A Sustainable Environmentally Friendly Pre-Treatment Process towards Knit-Dyeing Technology Convenient for Environmental Perspective

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Abstract. The use of enzymes in textile processing has made a major contribution to the development of textiles, in particular, textile wet processing. With temperatures of 95°C, a method of conventional scouring on cotton knitted fabric is conducted in a higher base medium (pH 10.5-12) with sodium hydroxide. This process is gradually being replaced by an eco-friendly and economical approach using enzymes that obviate the non-cellulosic impurities. In this work, cotton knit fabric samples were bio-scoured by BioPrep® Fusion (bio-scouring enzyme) and also, they were scoured by using the traditional method. Then, the physicochemical parameters of the effluents derived from the scouring process have been investigated in this study. The physical parameters include Electrical Conductivity (EC), Total Solids (TS), Total Suspended Solids (TSS), and Total Dissolved Solids (TDS). Moreover, the chemical parameters involve pH, Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), and Alkalinity. Furthermore, the impacts of traditional caustic soda scouring on environmental contamination have also been investigated using a number of different techniques and apparatus and compared to that of enzymatic scoured fabrics. The results of the physicochemical parameters of the effluents test reveal greater ecological developments in the use of the enzyme. Based on the findings of this analysis, it is often understood that the bio-scouring process performed far better as opposed to the traditional method, and also the method is environmentally friendly and sustainable. Hence, enzymatic scouring can be utilized as an eco-friendly in contrast to traditional caustic soda scouring in the knit-dyeing factory.

1. Introduction
Industry plays a crucial role in Bangladesh’s economy. In Bangladesh, development has been focused primarily on garments that are export-oriented businesses. The reason for this is that Bangladesh's textile manufacturing industry is the largest foreign currency earner and contributes greatly to Bangladesh’s GDP [1]. A significant number of other textile industries have been set up to support the
clothing industry, and more are coming up in the near future. Indeed, the textile industry covers a number of industries with operational activities and forms as different as its items. In textile manufacturing, before the grey fabric is converted into a finished fabric, it must pass through a number of chemical treatments which involves desizing, scouring, mercerization, bleaching, and washing. A lot of toxic chemicals and auxiliaries are used in these phases. The pre-treated fabric is coloured with the use of material colouring and finished with stenter and compacter machine [2]. Hemi-celluloses, non-cellulosic and foreign additives are partly or entirely eliminated in the numerous pre and post-production processes during the manufacture of fabrics [3-7]. Pre-treatment and dyeing results in a significant amount of effluents have a detrimental effect on the ecosystem. Furthermore, since a variety of harmful substances are used in the conventional scouring method, it is quite accountable for increasing the values of physicochemical properties in the wastewater and raising the unnecessary impact on the ecosystem. It is generating: a. more than half of the overall BOD b. just below half of the entire amount of COD and c. a fifth of the overall pollution level generated throughout the fabric manufacturing process [8-9].

In Bangladesh, the dyeing industry consumes so much as 350 liters of water to manufacture one kilogram of cloth. This is around eight times as much water as is considered best practice globally. This field is dedicated to washing, dyeing, and finishing fabrics that use about 79000 million cubic meters of water each year, which is about 3% of all groundwater extraction worldwide and constitutes more than one-tenth of the water used by all forms of industry [10-11]. It is evaluated that 65 liters of water are needed for handling a meter of fabric. Hence, it is easy to understand that a huge volume of wastewater is created each day from distinctive textile factories. Roughly 15,000 cubic meters of untreated industrial wastewater are thrown out to low-lying lands, rivers, and other bodies of water that create an adverse effect on the ecological balance. It is also forecasted that around 348 million cubic meters of wastewater will be generated by traditional dyeing practices in 2021[12-17]. In Bangladesh, caustic pre-treatment is as common compared to bio-scouring. Because of the low value and resource availability, nobody is worried about the environmental affects. Untreated and poorly processed wastewater causes environmental contamination as well as health threats. Industrial waste is considered to have a harmful effect on natural life by directly detrimental action. The ecological balance is deteriorating as a result of pollution.

The core of Bangladesh’s economy, while creating more jobs, is also destroying the environment. Wherever possible, there is a necessity to detach development from the growing use of coal, oil, water, and energy and minimize the usage and the consequent outcomes of environmental assets. The output from manufacturing processes as well as waste to the environment should be decreased in quantity and effect.

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This work is a little approach to mitigate the afore-mentioned causes of our country's environmental pollution as well as the world as a whole. This paper includes a comparative study of the investigation on the environmental contamination of using conventional caustic soda scouring and enzymatic scouring in the knit-dyeing factory.

The research goals and priorities of the study were to carry out conventional caustic soda scouring process and also enzymatic bio-scouring process on cotton knitted fabric, and to analyze the physicochemical parameters of the industrial effluents obtained from the processes referred to above.

1.1. Design of Experiment
The experimental design is displayed in the below.
2. **Method and Materials**

2.1. **Raw Materials**

The utilized substances are-
- 100% single jersey cotton fabrics (Grey Fabric)
- Scouring Chemicals, Auxiliaries, and Water.

2.2. **Fabric Construction**
- Types of fabrics: 100% Cotton (Grey)
- Count: 28’s
- GSM: 160

2.3. **Scouring Process**

*Bio-scouring Process:* For bio-scouring, 0.80% BioPrep® Fusion (bio-scouring enzyme) was used. pH buffer (i.e., citric acid) to set scouring bath at a favorable pH for enzyme to act. The pH of the scouring bath was 6.5. Moreover, 1 g/L PERSOCLAN STN (wetting agent), 0.05 g/L ANTIFOAMING JET (anti-foaming agent), 1 g/L FEROL-ZOM (detergent), M: L=1:8, temperature 55°C, and time 30 minutes were used. A process curve for bio-scouring is shown in the following:
Figure 2. Scouring the enzyme curve

Description of the bio-scouring process: Firstly, the dye bath was set with fabric at room temperature with the required quantity of water. Then, wetting agent, anti-foaming agent, citric acid, BioPrep® Fusion(bio-scouring enzyme), and detergent were added in the dyeing machine. Afterwards, the temperature was raised at 55°C for 30 minutes, and increased the temperature at 80°C, kept it for 10 minutes. Drain the liqueur out of the dye bath, after completing the scouring process. Later, the cloth was rinsed with cold water, and it is prepared for the following subsequent processes.

Conventional Scouring Process: For conventional scouring, 1 g/L NaOH and 2 g/L soda ash were used. Because water used in the wet processing technology may have hard water substances, i.e., water hardness found 27 ppm (parts per million), that’s why 0.20 g/L SHUNTEX XPA (sequestering agent) was used. Moreover, 1 g/L PERSOCLAN STN (wetting agent), 2 g/L FEROL-ZOM (detergent), 1 g/L RUBINE OS (anti creasing agent), 0.05 g/L ANTIFOAMING JET (anti-foaming agent), 1.50 g/L citric acid, and M:L=1:10, temperature 100°C, pH 11, time 60 min was used.

Description of the Process of Traditional Scouring: At first, the cloth is taken into the dye bath. This process is operated with fabric at room temperature with the required quantity of water. Then, all chemical auxiliaries were added in the dye bath. After a few minutes later, alkali with soda ash was added and raised the temperature to 95°C. This process was operated at this temperature for 60 minutes. Drain the liqueur out of the dye bath, after completing the scouring process. Afterwards, rinsing or overflow was given with cold water and hot water (around 90°C). Neutralize the fabric with citric acid treatment for 10 minutes and carry out the next process.

2.4. Physicochemical Parameters Test
The effluents were collected, and numerous physicochemical parameters of the effluents test were carried out after all the pre-treatment processes of both samples.
Figure 3. Scouring the alkali curve

**Biochemical Oxygen Demand:** The levels of oxygen are needed for the oxidative activity of organic compounds in water is called Biochemical Oxygen Demand. BOD is not only used for water quality control and assessment, but it is also used in ecology and environmental sciences. This test is carried out in the following standard procedure (*Method APHA 5210B*): the known sample volume has its initial dissolved oxygen content registered. After five days of incubation at 20°C, the sample is obviated from the incubator, and the final content of the dissolved oxygen is obviated. The value of BOD is determined based on the degradation and the amount of the sample used. Determine the BOD value according to the following formula:

\[
\text{BOD} = \frac{(\text{Burette Reading for sample at } \text{DO}_5 - \text{DO}_t) - \text{Blank correction}}{\text{Dilution factor}}
\]

Where \(\text{DO}_5\) = initial Dissolved Oxygen, and \(\text{DO}_t\) = day five after incubation.

**Chemical Oxygen Demand:** The levels of oxygen are needed to oxidize the organic and inorganic matters present in water called COD. This test is carried out in the following procedure (*Method APHA 5220B*): Organic and oxidizing inorganic compounds in the sample are oxidized by \(\text{K}_2\text{Cr}_2\text{O}_7\) in a 50 % \(\text{H}_2\text{SO}_4\) solution at its boiling point. \(\text{Ag}_2\text{SO}_4\) is used as a catalyst, and \(\text{HgSO}_4\) is used to eliminate the effects of chloride. Using standard \(\text{Fe(NH}_4\text{)}_2\text{(SO}_4\text{)}_2\) that uses the \(\text{C}_36\text{H}_24\text{FeN}_6^{++2}\) as an indicator, the excessive quantity of \(\text{Cr}_2\text{O}_7^{2-}\) is titrated. Determine the COD value according to the following formula:

\[
\text{COD} = \frac{(V_1 - V_2) \times M \times 8000}{\text{mL of sample taken}}
\]
Where \( V_1 = \text{FAS} \) [Ammonium iron(II) sulfate] solution needed for the blank (in mL), \( V_2 = \text{FAS} \) solution needed for the sample (in mL), and \( M = \text{Molarity of FAS solution.} \)

**Alkalinity:** Alkalinity is measured by volumetric titration at 0.02 N H\(_2\)SO\(_4\) and reported as CaCO\(_3\) equivalent.

**pH and Electrical Conductivity:** pH is the calculation of the acidic or basic state of the negative logarithm of the concentration of hydrogen ion in sample water. pH test is carried out using a standard Pinpoint pH meter. A measurement of electrical solution conductivity assesses its ability to conduct electricity. Using a multimeter (Apera Instruments AI316 Premium Series PC 60), conductivity (mS/cm) value was found directly.

**Total Solids:** Total Solids (TS) refer to the thing remaining as residual after volatilization and drying up at 105°C for a period of 24 hours. Method APHA 2540 B is carried out to determine the TS. Calculate total solids (TS) as follows:

\[
\text{Total Solids} = \frac{(W_2 - W_1) \times 1000}{\text{sample volume}}
\]

(5)

Where, \( W_2 = \text{weight of filter paper + dried residue, and } W_1 = \text{weight of filter paper.} \)

**Total Dissolved Solids:** TDS are solid particles in water, undergoing via the filter. TDS is resolved by Method APHA 2540 C.

\[
\text{Hence, } \text{TDS} = \text{TS} - \text{TSS}
\]

(6)

**Dissolved Oxygen:** DO is that the levels of oxygen are dissolved in water, necessary for safe streams and rivers. The value of Dissolved Oxygen may be an indication of how dirty water is and how well water can sustain aquatic plant and animal life. The most common method for the measurement of Dissolved Oxygen is the dissolved oxygen meter and sensor (Model: JPB-70A).

**Total Suspended Solids:** TSS are solid particles in water, be contained by a filter. According to Method APHA 2540 D is carried out the test.

\[
\text{TSS} = \frac{(W_4 - W_3) \times 1000}{\text{sample volume}}
\]

(7)

Where, \( W_4 = \text{wt. of filter paper + dried residue, and } W_3 = \text{wt. of filter paper.} \)

3. **Results and Discussions**

Physicochemical parameters test results table and pictorial description of physicochemical test parameters are displayed in the below.

3.1. **Discussion**

After bio-scouring, the effluents value of the BOD (1003.7 ppm) is to a higher degree lower than that of traditional caustic soda scouring (1812.33 ppm). This reason is the usage of enzyme instead of caustic soda and soda ash. Also, lower temperatures maintain at 55°C. Compared to the value of bio-scouring effluents (2225 ppm), the COD result of caustic soda scouring effluents (3329 ppm) is considerably higher. A number of organic and inorganic matters, which are wetting agent, anti creasing agent, antifoaming agent, citric acid, detergent, caustic soda, soda ash, and sequestering agent, were used in the traditional scouring process what to oxidize required for the massive amount of oxygen. That is why the value of traditional scouring is substantially as high as bio-scouring.
### Table 1. Test Result of Physicochemical Parameters

| Sample No. | Material of effluents | Parameters | Units | Results | Department of Environment Standards for waste from industrial units |
|------------|-----------------------|------------|-------|---------|---------------------------------------------------------------|
|            |                       |            | N<sup>1</sup> | Mean | SD<sup>2</sup> |
| Sample No. 1 (Effluent from conventional scouring) | Detergent, Wetting agent, Caustic soda, soda ash, Cotton waste, citric acid, Sequestering agent, anti-foaming agent, anti-creasing agent | Biochemical Oxygen Demand | ppm | 3 | 1812.3 | 12.81 | 50 |
| | | Chemical Oxygen Demand | ppm | 3 | 3229 | 29.81 | 200 |
| | | Dissolved Oxygen | ppm | 3 | 1.13 | 0.02 | 6 |
| | | Electrical Conductivity | mS/cm | 3 | 28.51 | 0.07 | 12 |
| | | Total Solids | ppm | 3 | 14533 | 28.58 | – |
| | | Total Suspended Solids | ppm | 3 | 267 | 10.2 | 150 |
| | | Total Dissolved Solids | ppm | 3 | 14266 | 26.09 | 2100 |
| | | Alkalinity | ppm | 3 | 939.67 | 7.59 | 500 |
| | | pH | – | 3 | 11.82 | 0.22 | 6–9 |
| Sample No. 2 (Effluent from bio-scouring) | BioPrep® Fusion (bio-scouring enzyme), Wetting agent, Detergent | Biochemical Oxygen Demand | ppm | 3 | 1003.7 | 3.3 | 50 |
| | | Chemical Oxygen Demand | ppm | 3 | 2225 | 19.65 | 200 |
| | | Dissolved Oxygen | ppm | 3 | 2.77 | 0.01 | 6 |
| | | Electrical Conductivity | mS/cm | 3 | 6.29 | 0.02 | 12 |
| | | Total Solids | ppm | 3 | 3316 | 25.96 | – |
| | | Total Suspended Solids | ppm | 3 | 160 | 2.94 | 150 |
| | | Total Dissolved Solids | ppm | 3 | 3156 | 23.04 | 2100 |
| | | Alkalinity | ppm | 3 | 707 | 5.35 | 500 |
| | | pH | – | 3 | 6.45 | 0.08 | 6–9 |

<sup>1</sup> Number of observations, and <sup>2</sup> Standard Deviation

The findings have shown that the DO value of bio-scouring effluents (2.77 ppm) is considerably higher in comparison to conventional cotton scouring effluents (1.13 ppm). Since the quantity of oxygen, dissolving in water (DO), depends on temperature, warmer water can contain less oxygen than colder water. Here, the bio-scouring process was operated at lower temperatures (55°C), whereas
conventional caustic scouring was conducted nearly at boiling temperature (95°C). Moreover, the Electrical Conductivity of bio-scouring (6.29 mS/cm) was very satisfactory because no electrolyte was present in the wastewater, and its purification was also good. However, the traditional sample (28.51 mS/cm) shows less purity because its value of EC is higher compared to standard water. Because of the rise of ions, the value of conductivity increases. As long as a variety of toxic chemical compounds are used in the conventional pre-treatment step, EC’s value is as high compared to bio-scouring. As opposed to sampling 1 (14266 ppm), the TDS result of sampling 2 (3156 ppm) is well satisfactory because of using enzyme during the scouring process. We know that the existence of sodium, potassium, and chloride ions raise the amount of TDS.

![Graphical representation of BOD, COD, and Alkalinity values after scouring](image)

**Figure 4.** Graphical representation of BOD, COD, and Alkalinity values after scouring

![Graphical representation of TS, TSS, and TDS values after scouring](image)

**Figure 5.** Graphical representation of TS, TSS, and TDS values after scouring
In sample 1, caustic and soda ash were used during the traditional scouring process because soda ash, which is the main compound, raises the alkalinity value. As a result, the alkalinity (939.67 ppm) shows higher value. On the contrary, using enzyme instead of using caustic soda and soda ash decreases the alkalinity value (707 ppm) of the wastewater in sample 2. Compared with the value of TSS for sample 1 (267 ppm), the value of TSS for sample 2 (160 ppm) is considerably lower. Caustic soda, soda ash and a number of inorganic compounds were also used in the traditional caustic cotton scouring process; thus, sample 1 reveals higher values for the TSS. Because of the most suspended solids are made up of a lot of inorganic substances.

4. Conclusions
In Bangladesh, as a result of the textile dyeing and printing industry, the threats faced by textile wastewater containing both inorganic and organic compounds have a significant adverse effect on the local climate. These can be extremely poisonous. Since the conventional scouring process is extremely using in this day and age in Bangladesh, it has a really detrimental impact on the environment. This work has shown that many toxic and inorganic chemical compounds are included in the traditional scouring process, which is very much responsible for increasing the quantity of BOD, COD, DO, TSS and TDS; hence, a number of developed countries are abandoning the caustic scouring process replacing environmentally friendly bio-scouring processes. This study also revealed that as the selection of enzymatic scouring ensures the lesser ecological effect than traditional caustic soda cotton processing, it has improved environmental change. Because it decreases the BOD, COD, TDS, alkalinity, and pH of the wastewater, also raises the DO value in the scouring phase. Furthermore, it decreases the environmental footprint by reducing 45 per cent of BOD, 32 per cent of COD, and 40 per cent of TSS compared to the traditional caustic soda scouring process. A significant proportion of TDS value reduced in the enzymatic scouring as opposed to the caustic soda scouring. This exploration is a small path to better reliable practices that would inspire textile and apparel designers, suppliers, merchandisers, buyers, and consumers to incorporate a range of sustainability issues into their work; therefore, raising consciousness and moving them to environmentally friendly practices in the textile sector for a healthier and greener environment. Last but not least, for the betterment of our country, every person participating in textile manufacturing ought to be eco-friendly in order to conserve our environment and sustain the image of ours ready-made clothing in developed countries.

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References

[1] Rabbi MA, Hasan MM, Akhter A 2016 Environmental Science: An Indian Journal 12(4) 133-136.
[2] Mojsov K 2012 International Journals of Marketing and Technology 2(9) 256-275.
[3] Li Y, Hardin ZR 1997 Cellulose 29(8) 71-76.
[4] Chung C, Lee M, Choe EK 2004 Carbohydrate Polymers 58(4) 417-420.
[5] Menezes E, Choudhari M 2011 Textile Dyeing 11 221-240.
[6] Karmakar SR 1999 Chemical technology in the pre-treatment processes of textiles, Elsevier, Amsterdam.
[7] Jothi D 2015 World Journal of Engineering and Technology 3(03) 37-44.
[8] Hardin IR 2010 Enzymatic treatment versus conventional chemical processing of cotton. Woodhead Publishing, UK.
[9] Dobrowolski JW, Bedla D, Czech T, Gambus F, Gorecka K, Kiszcak W, Kuzniar T, Mazur R, Nowak A, Sliwka M, Tursunov O, Wagner A, Wieczorek J, Swiatek M 2017 Integrated Innovative Biotechnology for Optimization of Environmental Bioprocesses and a Green Economy Optimization and Applicability of Bioprocesses eds Purohit H, Kalia V, Vaidya A, Khardenavis A (Singapore: Springer) chapter 3 pp 27-71.
[10] Rabbi MA, Hossen J, Sarwar M, Roy PK, Shaheed SB, Hasan MM 2018 Current World Environment 13(2) 206-214.
[11] Aktar P, Moonajilin MS 2017 International Journal of Engineering and Information Systems 1(6) 105-118.
[12] Sultana Z, Ali ME, Uddin MS, Haque MM 2013 Journal of Environmental Protection 4(3) 301-308.
[13] Parvathi C, Maruthavanathan T, Prakash C 2009 The Indian Textile Journal 22.
[14] Toprak T, Anis P 2017 J Textile Eng Fashion Technol. 2(4) 429-442.
[15] Mia R, Selim M, Shamim AM, Chowdhury M, Sultana S, Armin M et al 2019 Journal of Textile Engineering & Fashion Technology 5(4) 220-226.
[16] Dobrowolski JW, Kobylarczyk J, Tursunov O, Toh SQ 2015 Integration of Local Eco-Innovation with Global Problems of Protection of the Natural Environment and Bio-Based Green Economy, In Proceedings : AASRI International Conference on Circuits and Systems (CAS), Atlantis Press, 9 25-28.
[17] Munnaf A, Islam MS, Tusher TR, Kabir MH, Molla MAH 2014 Journal of Environmental Science and Natural Resources 7(1) 257-263.
[18] O’Neill C, Hawkes FR, Hawkes DL, Lourenço ND, Pinheiro HM, Delée W 1999 Journal of Chemical Technology and Biotechnology 74(11) 1009-1018.
[19] Hannan MA, Rahman MA, Haque MF 2011 DUET Journal 1(2) 49-59.
[20] Islam MM, Mahmud K, Faruk O, Billah MS 2011 International Journal of Environmental Science and Development 2(6) 428-436.
[21] Jolly YN, Islam A, Mustafa AI 2009 Journal of Bangladesh Academy of Sciences 33(1) 99-106.
[22] Aslam MM, Baig MA, Hassan I, Qazi IA, Malik M, Saeed H 2004 Electronic Journal of Environmental, Agricultural and Food Chemistry 3(6) 804-811.
[23] Sultana MS, Islam MS, Saha R, Al-Mansur MA 2009 Bangladesh Journal of Scientific and Industrial Research 44(1) 65-80.
[24] Kamal AKI, Ahmed F, Hassan M, Uddin M, Hossain SM 2016 Pollution 2(2) 153-161.