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Effluent treatment in textile wet processing —Bleaching of polyester-cotton fabric

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Ecofriendly processes have been developed for the bleaching of carbonized and uncarbonized polyester-cotton blended fabrics with a view to reduce the water consumption and processing time. There is no significant difference in the whiteness values, *K*/*S* values and fastness properties of samples bleached by the conventional method and those bleached by the two suggested formulations. Further, by employing ecofriendly processes, there is significant decrease in volume of effluent generated. Both the formulations are found to be techno - economically viable.

Keywords: Bleaching, Ecofriendly processing, Effluent treatment, Polyester - cotton blend, Wet processing
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1 Introduction

Processing units discharge thousand tones of pollutants especially in the form of BOD (biological oxygen demand), COD (chemical oxygen demand) and TDS (total dissolved solids).[1] As a result, the running costs relating to the washing medium (water supply and effluent purification) are very high.[2] Although managing waste water from the textile industry is very difficult, it can be dealt with successfully by beginning at the source to minimize the waste water that is produced and the amount of the chemicals present. Various waste water treatment processes are available which can be used to treat the waste water from this industry. However, it cannot be assumed that a simple system can be placed at any textile plant to successfully treat the waste water.[3-5] Successful waste water treatment of textile effluent requires thorough investigation of waste water characteristics, source reduction and the application of cleaner production principles, such as chemical substitution and process modifications to make the process of the final effluent treatment as simple as possible.[6-8] At the moment, bleaching is in the midst of a reorientation triggered by AOX problem and the ecotextile wave. While in many textile sector's, chlorine chemicals can be dispensed with completely, there is still no fully equivalent alternative to the combined hypochlorite and peroxide process for bleaching cotton knitted fabrics to full white.[9,10]

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Lokhande and Wasif[11,12] have developed ecofriendly bleaching process both for cotton and polyester- cotton blended fabrics, wherein potassium permanganate was used for bleaching in place of hypochlorite used in conventional bleaching followed by hydrogen peroxide bleaching with advantage.

Deo and Chinta have used redox system for bleaching with hydrogen peroxide, wherein without affecting the quality of bleaching the effluent load has been reduced drastically both for cotton fabric[13] and yarn.[14]

Deo and Paul[15] have developed an enzymatic method of carbonization by applying cellulase enzymes repeatedly on polyester-cotton fabrics for the complete removal of cotton component.

In the present work, an attempt has been made to reduce the effluent load during the carbonization and bleaching of polyester-cotton fabric for the decentralized processing sector. The bleaching of polyester-cotton blends after carbonization generates huge amount of effluent having high acidic *p*H and has to be treated separately. The cost of conventional effluent treatment is very high and hence an attempt has been made to modify the process so as to reduce the volume of effluent generated, thereby reducing the treatment cost.

2 Materials and Methods

2.1 Materials

Polyester-cotton (65:35) blended fabric (grey width, 48inch; ends per inch, 80; picks per inch, 84; warp count, 80 den; and weft count, 80 den) was used for bleaching after carbonization and polyester-cotton (65:35) blended fabric (grey width, 48inch; ends per inch, 40; picks per inch, 40; warp count, 88 den; and weft count, 80 den) was used for bleaching without carbonization.

The above blended fabrics have been chosen for the study as these were commonly used for bleaching in decentralized processing sector. Caustic soda, sodium hypochlorite, hydrogen peroxide, sulphuric acid, soda ash, sodium hydrosulphite, diammonium phosphate and acetic acid, all of AR grade, were used. Peroxide stabilizer AWNI, hydrated calcium oxide, alum, polyelectrolyte, and activated carbon, all of commercial grade, were used. Coralene Brill.Red F3BS (Disperse Red 343) and Chemifix Brill. Red HE7B (Reactive Red 141) dyes were used.

2.2 Methods

The experiments were carried out first in the laboratory and then scaled up on the industrial scale in decentralized process house. The fabric was bleached by conventional method as well as by using laboratory prepared Formulations I and II. The processing sequence was changed in both the formulations and the effluent generated was collected for the analysis. The results obtained have been compared with those of conventional method of bleaching.

Bulk trials for conventional bleaching process as well as the proposed modified Formulation I and Formulation II were carried out in a decentralized typical process house. The batch size of the fabric was 100 kg. The chemicals (commercial grade) used were purchased by the process house in bulk as per the usual practice of the industry.

2.3 Bleaching of Carbonized Blended Fabric

2.3.1 Conventional Bleaching Process

The polyester-cotton blended fabric after loading on jigger was run for two ends in 70% sulphuric acid followed by two ends for aeration and two ends for cold wash. The fabric was neutralized by running for two ends in soda solution followed by two cold washes. The fabric was given two ends in sodium hypochlorite solution (3 gpl available chlorine) at room temperature. The fabric was then given aeration by running two ends followed by two more ends for washing. The fabric was then treated with 0.3% hydrogen peroxide (50%), 0.5% soda ash and 0.15% stabilizer AWNI for four ends at 80°C. The fabric was run for two ends for washing and neutralized with dilute acetic acid.

2.3.2 Formulation I

The polyester-cotton blended fabric after loading on jigger was carbonized in the above manner and after adjusting the *p*H at 10, it was run for four ends in 0.4% hydrogen peroxide (50%), 0.5% soda ash and 0.15% stabilizer AWNI at 80°C followed by two cold washes and neutralization.

2.3.3 Formulation II

The polyester-cotton blended fabric after loading on jigger was carbonized in the above manner and after adjusting the *p*H at 10, the fabric was run for two ends in 0.25% solution of sodium hydrosulphite at room temperature. Later 0.4% hydrogen peroxide (50%) and 0.5% soda ash were added to the same bath and four ends were given at 80°C. The fabric was then washed by running two ends in water and neutralized.

2.4 Bleaching of Uncarbonized Blended Fabric

2.4.1 Conventional Bleaching Process

The polyester-cotton blended fabric after spotting and loading on jigger was run for four ends for scouring with 0.3% caustic soda, 0.6% soda ash, 0.1% wetting agent at boil followed by two ends in hot water and two ends in cold water. The fabric was then treated with sodium hypochlorite (2.0 gpl available chlorine) at room temperature for four ends. The fabric was then run for two ends for cold wash. The fabric was given four ends in 0.75% hydrogen peroxide (50%), 0.5% soda ash, 0.25% stabilizer AWNI and 0.5% optical whitener at 80°C and run for two ends for washing and two ends through acetic acid for neutralization.

2.4.2 Formulation I

The polyester-cotton blended fabric after spotting and loading on jigger was run for four ends for scouring with 0.3% caustic soda, 0.6% soda ash, 0.1% wetting agent at boil. The fabric was given two ends in hot water wash followed by two ends in cold water wash. The fabric was then treated for two ends with 0.25% sodium hydrosulphite and in the same bath 0.75% hydrogen peroxide (50%), 0.5% soda ash, 0.25% stabilizer AWNI and 0.5% optical whitener were added and four ends were given at 80°C. The fabric was washed by running two ends in water and two ends through acetic acid for neutralization.

2.4.3 Formulation II

The polyester-cotton blended fabric after spotting and loading on jigger was given combined scouring cum bleaching in the same bath. Fabric was given four ends in a solution containing 0.1% wetting agent, 1% caustic soda, 0.5% reducing agent, and 0.25 % stabilizer AWNI. In the same bath, 0.75% hydrogen peroxide (50%) was added in two installments and total six ends were given. In the second installment, along with hydrogen peroxide 0.5 % optical whitening agent (2B) was added. The scoured bleached fabric was given two ends in hot water followed by two ends in cold water and two ends through acetic acid for neutralization.

All the fabrics bleached by conventional and Formulations I and II were dried on stenter at 80°C. Eleven minutes are required to complete one end on jigger.

2.5 Treatment of Effluent

The effluent[16,17] from all the unit processes, like desizing, scouring and bleaching, was collected and treated as per the process sequence shown in Fig. 1.

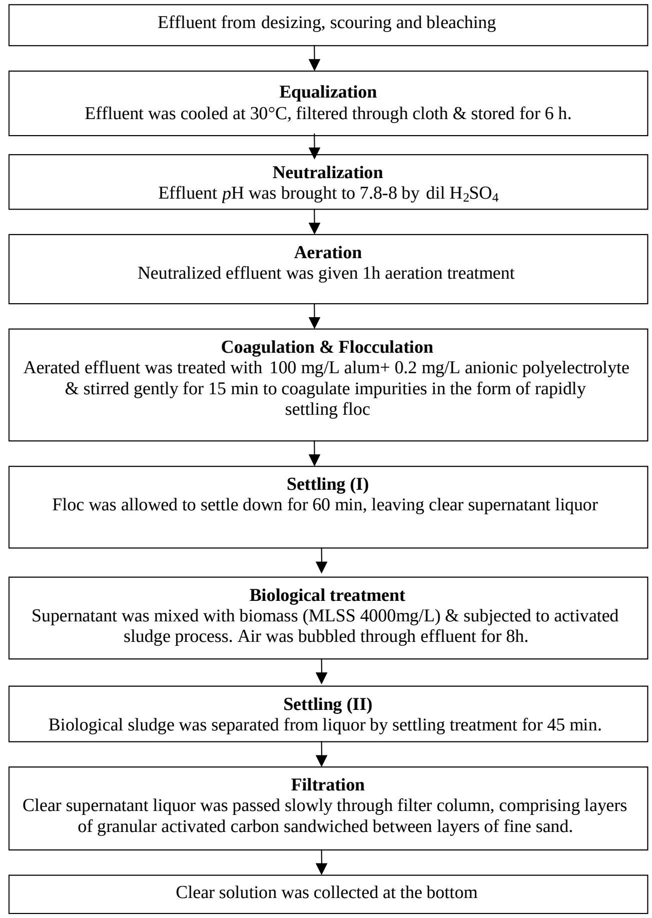

Fig. 1 — Process steps for effluent treatment

2.6 Testing and Analysis

The whiteness of bleached fabrics was measured on a high volume tester (930 Colorimeter). This instrument directly gives the values of reflection and whiteness (Hunter Scale). The *p*H, suspended solids (SS), total dissolved solids (TDS), biochemical oxygen demand (BOD), chemical oxygen demand (COD) were determined using the standard methods of analysis.

3 Results and Discussion

As regards bleaching of carbonized blended fabric, it can be seen from Table 1 that for conventional method of carbonization and bleaching, the time required is 253 min whereas the Formulations I and II require 209 min and 231 min, thereby saving 17.39% and 8.69% of the time respectively. The reduction in time is due to lesser number of ends (6) required for Formulations I and II. The quantity of water required per kilogram of fabric bleaching is reduced from 50 L for conventional method to 38 L for both the formulations.

For bleaching of uncarbonized bended fabric, it can be observed that for conventional method of bleaching, the number of ends required is 24 whereas Formulations I and II require 18 and 16 ends respectively. The time required for conventional bleaching is 440 min whereas the Formulations I and II require 360 min and 320 min respectively. The saving in time of bleaching is found to be 18.18 % for Formulation I and 36.36 % for Formulation II. The quantity of water required for per kilogram of fabric bleaching is reduced from 20 L for conventional bleaching to 15 L for Formulations I and 9L for Formulation II. The saving in water is 25% for Formulation I and 55% for Formulation II. The whiteness values for conventionally bleached sample are 94.0602, whereas Formulations I and II bleached samples show whiteness values of 89.732 and 94.831 respectively. Formulations II bleached sample gives slightly better whiteness as compared to that of conventionally bleached sample, indicating that the redox system employed with sodium hydrosulphite followed by peroxide bleaching is more effective. The lower values of whiteness in Formulation I may be due to the elimination of hypochlorite bleaching.

It can be observed from Table 2 that for bleaching of carbonized fabrics, the chemical cost of bleaching

Table 1 — Effect of different bleaching methods on process parameters

Fabric	Method	No. of ends required	Total time required min	Savings in time %	No. of washings required	Total quantity of water required/kg of fabric, L	Saving in water, %	Whiteness (Hunter) %
Carbonized	Conventional	23	253	-	08	50	-	82.310
polyester-cotton	Formulation I	19	209	17.39	06	38	24	82.172
blended	Formulation II	21	231	8.69	06	38	24	83.971
Uncarbonized	Conventional	24	440	-	08	20	-	94.060
polyester-cotton	Formulation I	18	360	18.18	06	15	25	89.732
blended	Formulation II	16	320	36.36	04	09	55	94.831

Table 2 — Effect of bleaching sequences on costing per 100 kg of fabric

Fabric	Method	Chemical cost of bleaching Rs	Savings in chemical cost %	Quantity of water required L	Cost of water Rs	Savings in cost of water, %	Total bleaching cost Rs	Total savings in cost, %
Carbonized	Conventional	180	-	5000	75	--	255	-
polyester-cotton	Formulation I	160	11.11	3800	57	24	217	13.91
blended	Formulation II	171	5.0	3800	57	24	228	9.13
Uncarbonized	Conventional	149	-	2000	10.66	-	159.66	-
polyester-cotton	Formulation I	115	22.81	1500	07.99	25.04	122.99	22.96
blended	Formulation II	68	54.36	900	04.79	55.06	72.79	54.40

by conventional method is Rs 180 as against Rs 160 and Rs 171 for Formulations I and II respectively. Further, since lesser quantity of water is required for both Formulations I and II (3800 L each) as compared to 5000 L for conventional method, the water costs are Rs 57 each for Formulation I and Formulation II as against Rs 75 for conventional method. Thus, Formulations I and II show 11.1% and 5% savings in chemical costs respectively. Similarly, Formulations I and II show 24% savings in water cost. The overall savings obtained with Formulations I and II are 13.91% and 9.13%.

For bleaching of uncarbonized blended fabric, the chemical cost of bleaching by conventional method is Rs 149 as against Rs 115 and Rs 68 for Formulations I and II respectively. Further, since lesser quantity of water is required for Formulations I and II, i.e 1500 L for Formulation I and 900 L for Formulation II as compared to 2000 L for conventional method, the water costs are Rs 7.99 for Formulation I and Rs 4.79 for Formulation II as against Rs 10.66 for conventional method. Thus, Formulations I and II show 22.81 % and 54.36 % savings in chemical costs respectively. Similarly Formulations I and II show 25.04% and 55.06% savings in water cost respectively. The overall savings obtained with Formulations I and II are 22.96% and 54.40% respectively.

Table 3 — Evaluation of dyed fabric for fastness properties

Method	*K/S* value	Wash fastness	Light fastness	Rub fastness
Conventional	13.820	4-5	5-6	4-5
Formulation I	13.861	4-5	6	4-5
Formulation II	13.802	4-5	6	4-5

Dyeability studies of samples dyed with Coralene Brill. Red F3BS (Disperse Red 343) and Chemifix Brill. Red HE7B (Reactive Red 141) show that there is no significant difference in the *K/S* values of conventionally bleached sample and those bleached and dyed with Formulations I and II (Table 3). Though wash fastness and rub fastness ratings for the conventional method and for Formulations I and II are similar (4-5), the light fastness values for Formulation I and II bleached and dyed samples are slightly better than that for conventionally bleached and dyed samples.

Table 4 shows the characteristics of the effluent generated. Due to the use of sulphuric acid in the carbonization process, the *p*H of the effluent is highly acidic. The suspended solids and total dissolved solids are lower in Formulations I and II as compared to those in conventional method, which may be due to the reduced concentration of chemicals. Further, Formulation I shows BOD and COD values of 321 mg/L and 521 mg/L respectively, and Formulation II shows BOD and COD values of 329 mg/L and 542 mg/L respectively. Conventional method shows highest values of BOD (421 mg/L) and COD (697 mg/L). Lower values of BOD and COD for Formulations I and Formulation II as compared to conventional method indicate the less pollution load. Hence, both the formulations are found to be more ecofriendly as compared to conventional method.

The values of *p*H indicate the alkaline nature of the effluent collected after bleaching of polyester- cotton blended fabric. The suspended solids show slightly higher values for Formulation I (620 mg/L) and Formulation II (608 mg/L) as against 601 mg/L for conventional method of bleaching. The same trend is found with total dissolved solids values, i.e. 1900 mg/L and 1927 mg/L for Formulations I and II respectively as against 1953 mg/L for conventional method of bleaching. This may be due to reduction in water consumption in Formulations I and II, because of which the concentration level of SS and TDS slightly goes up. The BOD values are found to be slightly lower, i.e. 500 mg/L and 437 mg/L for Formulations I and II respectively as against 555 mg/L for conventional method. The same trend is also found with chemical oxygen demand, i.e. 1213 mg/L and 1110 mg/L for Formulations I and II respectively as against 1430 mg/L for conventional method. The reason may be due to combined single step bleaching with reduced number of chemicals in the case of Formulations I and II.

It can be observed from Table 5 that the treated effluent from bleaching of carbonized fabric shows *p*H 7.5 for conventional as well as for Formulations I and II. Further, Formulation II shows lowest SS (24 mg/L) and TDS (474 mg/L) and Formulation I shows SS and TDS values of 27mg/L and 484 mg/L respectively. The treated effluent due to conventional method shows highest values of SS (41 mg/L) and TDS (591 mg/L). As regards BOD and COD values, Formulation II shows the lowest values of 24 mg/L and 118 mg/L respectively and Formulation I shows BOD and COD values of 25mg/L and 124mg/L respectively. Conventional method shows the highest BOD (29mg/L) and COD(132 mg/L) values.

Bleaching of uncarbonized blended fabric shows *p*H 7.5 for conventional as well as for Formulations I and II. Further, Formulation II shows lowest SS (40 mg/L) and TDS (513 mg/L) and Formulation I shows SS and TDS values of 40mg/L and 579 mg/L

Table 4 — Analysis of waste water generated by different methods

Fabric	Method	*p*H	Suspended solids mg/L	Total dissolved solids mg/L	Biochemical oxygen demand mg/L	Chemical oxygen demand mg/L
Carbonized polyester-cotton blended	Conventional	2.2	685	1871	421	697
	Formulation I	2.1	647	1801	321	521
	Formulation II	2.2	659	1816	329	542
Uncarbonized polyester-cotton blended	Conventional	9.0	601	1953	555	1430
	Formulation-I	9.0	620	1900	500	1213
	Formulation- II	8.7	608	1927	437	1110

Table 5 — Analysis of treated waste water

Fabric	Method	*p*H	Suspended solids mg/L	Total dissolved solids mg/L	Biochemical oxygen demand mg/L	Chemical oxygen demand mg/L
Carbonized polyester-cotton blended	Conventional	7.5	41	591	29	132
	Formulation I	7.5	27	484	25	124
	Formulation II	7.5	24	474	24	118
Uncarbonized polyester-cotton blended	Conventional	7.5	48	610	28	135
	Formulation I	7.5	40	579	26	130
	Formulation II	7.5	40	513	25	126
	Maharashtra Pollution Control Board (PCB) norms	5.5-9.0	100	2100	30	250

Table 6 — Effluent treatment cost for bleaching of 100 kg carbonized polyester-cotton fabric

Method	Effluent generated L	Effluent treatment cost, Rs		Saving in treatment cost, %	
		Caustic soda	Lime	Caustic soda	Lime
Conventional	5000	1400	962.5	—	—
Formulation I	3800	1064	731.5	24	24
Formulation II	3800	1064	731.5	24	24

Table 7 — Neutralization cost with various alkalies

Chemical	Neutralization cost / litre of effluent, paise
Caustic soda	25
Hydrated lime	16.25
Savings/L (when lime is used), paise	8.75
% Saving	35

Table 8 — Effluent treatment cost for bleaching of 100 kg of uncarbonized polyester-cotton blended fabric

Method	Effluent generated L	Savings in effluent, %	Effluent treatment cost, Rs (A)	Savings in treatment cost, %	Bleaching cost Rs (B)	Total cost Rs (A+B)	Saving in total cost %
Conventional	2000	-	80	-	159.66	239.66	-
Formulation I	1500	25	60	25	122.99	182.99	23.70
Formulation II	900	55	36	55	72.79	108.79	54.62

respectively. The treated effluent due to conventional method shows highest values of SS (48 mg/L) and TDS (610 mg/L). As regards BOD and COD values, Formulation II shows the lowest values of 25 mg/L and 126 mg/L and Formulation I shows BOD and COD values of 26 mg/L and 130mg/L respectively. Conventional method shows the highest BOD (28 mg/L) and COD (135 mg/L). The values of *p*H, SS, TDS, BOD and COD in the treated effluent from conventional method and from Formulations I and II are within the norms set by Pollution Control Board. This indicates that if the pollution load is less in the raw effluent, the treatment becomes easier.

Table 6 shows the effluent treatment cost for bleaching of 100 kg of carbonized fabric. Since in the conventional method of bleaching, volume of effluent generated is maximum (5000 L), the treatment costs using caustic soda and lime are also high, viz. Rs 1400 and Rs 962.5 respectively. In case of both the formulations, the volume of effluent generated is 3800 L; hence the effluent treatment costs are low, i.e. Rs 1064 and Rs 731.5 for caustic soda and lime respectively.

It can be observed from Table 7 that for neutralization of acidic effluent, hydrated lime is more economical than caustic soda. Thus, if hydrated lime is used in the place of caustic soda, then net savings effected could be 35%.

Table 8 shows the effluent treatment cost for bleaching 100 kg of blended fabrics. Since in the conventional method of bleaching, volume of effluent generated is maximum (2000 L), the treatment cost is Rs 80. In case of both the formulations, the volume of effluent generated is 1500 L (Formulation I) and 900 L (Formulation II) hence the effluent treatment costs are low, i.e. Rs 60 and Rs 35 respectively for Formulations I and II. Total savings in effluent treatment cost and bleaching cost is 23.70 % for Formulation I and 54.62 % for Formulation II.

4 Conclusions

In the case of bleaching of both carbonized and uncarbonized polyester-cotton blended fabrics, though both the Formulations I and II show a net saving in time and water consumption as compared to conventional method, the savings in time is highest for Formulations I. There is no significant difference in the whiteness values of conventionally bleached samples and those bleached with Formulations I and II. Dyeability study shows no significant difference in *K*/*S* values of conventionally bleached samples and those bleached with Formulations I and II. In the modern era of water conservation, the Formulation II offers higher savings in water consumption. The parameters of the treated effluent are below the norms set by Pollution Control Board. Due to reduction in effluent load, the treatment cost of effluent is also reduced substantially. Since the caustic soda is costlier, the use of hydrated lime offers greater savings in neutralization cost. The Formulation II does not use any chlorine based bleaching agent, hence the process is totally ecofriendly.

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