Decolorization of the Reactive Dyed Cotton Fabrics with the Use of Ozone Assisted Eco-technology [⋆]

Ajinkya Powar [a,b,c,d,*], Anne Perwuelz [a,*], Nemeshwaree Behary [a],
Le Vinh Hoang [e], Thierry Aussenac [e], Carmen Loghin [c],
Stelian Sergiu Maier [c], Jinping Guan [d], Guoqiang Chen [d]

[a] *Ecole Nationale Supérieure des Arts et Industries Textiles (ENSAIT), GEMTEX Laboratory, 59056 Roubaix, France*

[b] *Université de Lille, Nord de France, F-59000 Lille, France*

[c] *Faculty of Industrial Design and Business Management, Gheorghe Asachi Technical University of Iasi, 67, 700050 Iasi, Romania*

[d] *College of Textile and Clothing Engineering, Soochow University, Suzhou 215000, China*

[e] *Institut Polytechnique UniLaSalle, Universitéd' Artois, ULR 7519, 19 rue Pierre Waguet, 60026 Beauvais, France*

Abstract

The textile coloration sector normally employs the color stripping process for correcting the various faults obtained during the wet processing operations like the printing and dyeing. However, the traditional method for the color stripping carries with it the possibility of grave ecological pollution. The purpose of this work is to investigate the new, ecological method such as ozone based process for the color stripping of the reactive dyed textiles. This novel ozonation process was performed at room temperature with low amount of chemical auxiliaries. The effects of different process parameters like the acidic pH, 45 g/m^3 ozone concentration and the treatment time of 30 minutes on the color stripping was investigated. Additional colorimetric analysis has been studied. The results indicate that the color stripping was achieved effectively at the atmospheric temperature with the ozonation process. This proposed technique was successfully implemented for the color stripping of different reactive dyes on the cotton substrate.

Keywords: Cotton dyed textiles; Decolorization; Eco technology; Ozone assisted process

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1   Introduction

In textile industry, dyeing process is normally used for the coloration of the textiles which needs to be performed with high accuracy. Sometimes during this process, we may come across the off shade problem, in which the achieved shade is far different than the desired shade. To rectify this problem normally the redyeing process or the color stripping of the dyed fabrics process is carried out. Traditional way of color stripping comprises of the use of oxidizing agent or reducing agent. Another approach to achieve effective color stripping is subsequent use of the reductive and oxidative methods [1].

Stripping process is often termed as back stripping or destructive stripping. Back stripping is performed when there is change in the depth of the shade and the destructive stripping consists of the chemical alteration of the dye [2]. Color stripping using reductive method consists of the use of reducing agents like sodium hydrosulphite, thiourea dioxide along with the use of the stripping assistants. Hydrogen peroxide, sodium chlorite and sodium hypochlorite are the most common oxidizing agents used in the industry [2].

Now a days, a lot of research is going to find out ecofriendly ways for the process development in textiles. Decolorization of the reactive dyed fabrics using the enzymes has already been carried out [3]. Advanced oxidation technologies like, ozone, peroxide combined with ozone and peroxide combined with ultrasound has already been carried out for the degradation of the wastewater containing the reactive dyes [4]. Utilisation of the ozone has merits such as energy and time savings (since ozonation is carried out at room temperature) and reduction in the environmental load (by avoiding the usage of harsh conventional process consisting of the reduction clearing chemicals). Hence the ozone use leads to environmental benefits and can be a good ecotechnology for use in textile industry [1]. The decolorization of the reactive dyed textiles in a sustainable manner is an essential need. In our study, ecotechnology like ozone assisted process was investigated for the color removal process. Two reactive dyed fabrics (Rouge Everzol C-RB 133, Orange Everzol FC reactive dyes) were used for the study of the color stripping. These dyestuffs were previously used for the coloration process of the pretreated cotton plain-weave fabric. Assessment of the color removed fabrics was done with the color stripping % and also with the colorimetric analysis.

2   Experimental

2.1   Materials

A 100% Ready for dyeing (RFD) cotton fabric of percale quality was used for this study. Orange Everzol FC (CI number not disclosed), Rouge Everzol C-RB 133(Reactive CI Red 198) dye (as shown in Fig. 1) supplied by the Achitex Minerva, were used for the dyeing experiments. Phosphoric acid and Caustic soda were laboratory grade for the experimental process.

2.2   Dyeing Procedure for the Cotton Fabrics

The dyeing process was carried out in a Jigger machine (Teinturerie Lenfant, France). Dyestuff of 1% of fabric weight was used with the standard recipe for the dyeing of cotton fabrics with reactive dyes (Rouge Everzol C-RB 133, Orange Everzol FC reactive dyes).
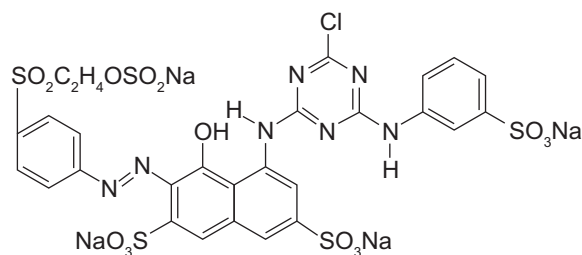
Fig. 1: Structure of C.I. Reactive Red 198

2.3 Color Removal from the Dyed Cotton Textiles

The dyed fabric samples (A4 size) were used for the color stripping experiments. The ozone assisted color stripping process was performed in a special reactor. Samples of around 40 g fabric were used. Capacity of the reactor was 60 litres of liquor. The treatment was carried out at pH 3, Ozone concentration 45 g/m^3 ozone concentration and treatment time for 30 minutes. From our previous work, the results demonstrated good decolorization of reactive dyed cotton using ozone at acidic pH. Hence, acidic pH was chosen for the ozone based decolorization [5]. After-treatment was carried out by cold washing of the fabrics under normal tap water.

The ozone assisted process was performed in a special reactor at the plateforme ozone (Uni-Lasalle, France). The ozone system consisted of the ozone injection by the venturi method and the circulation of the treatment liquor with the help of the pump. The detailed description of the ozonation set up has been discussed in our previous work [5]. The actual ozone set up is shown in Fig. 2.
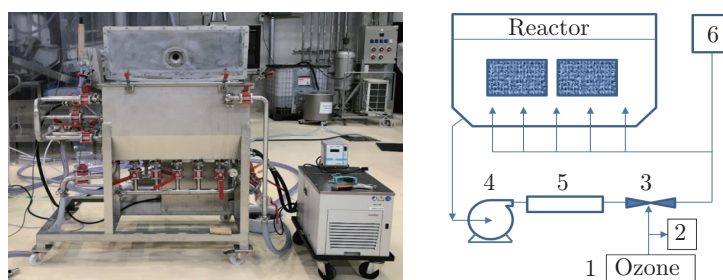

Fig. 2: Pilot ozonation (1 — ozone generator; 2 — ozone analyzer; 3 — venturi injection system; 4 — circulation pump; 5 — filter; 6 — dissolved ozone analyzer and pH meter) [5]

2.4 Color Stripping Percentage Measurements

The visual color of each fabric sample after the decolorization experiments was measured using the Konica Minolta CM3600d spectrophotometer (Konica Minolta Inc., Tokyo, Japan) as a K/S value (the colour strength). The sample was scanned on both the sides and at the various places to get accuracy in the color measurements. Generally, the K/S values at maximum absorbance wavelength are used traditionally to explain the buildup behaviour of the dyes on textiles [6]. The Color stripping was calculated based on the color strength values (K/S) of the dyed and the color stripped fabrics at 490 nm wavelength for orange and 530 nm for pink colored fabric. The

color stripping percentage were calculated using the following formula:

$$Stripping\ percent = \frac{[\frac{K}{S}\ value\ of\ dyed\ sample - \frac{K}{S}\ value\ of\ stripped\ sample]}{\frac{K}{S}\ value\ of\ dyed\ sample} \times 100$$

2.5   CIELAB Methodology for the Color Analysis

For the color analysis of the decolorized samples, the CIELAB methodology was applied. The CIELAB color space commonly known as CIE L*a*b* was defined in 1976 by the International Commission on Illumination (CIE). In the CIELAB color space, L* stands for the lightness (0 = black, 100 = white), a* stands for the red-green coordinate from (positive sign = red, negative sign = green) and b* stands for the yellow-blue coordinate from (positive sign = yellow, negative sign = blue) [7].

3   Results and Discussion

3.1   Colorimetric Analysis of Dyed Fabrics Treated with Ozonation Process

Figures 3 and 4 displays the K/S spectral curves of the reactive dyed fabrics (Orange Everzol FC, Rouge Everzol C-RB 133) stripped using the ozonation experimental conditions respectively. We can see considerable variation of the K/S values, and hence of stripping treatment, can be observed as a function of the ozonation treatment.

The decolorization of the textile fabric was studied by plotting a graph of the color strength vs. the wavelength. A graph of K/S vs Wavelength was plotted for all the decolorization experiments to study the color stripping phenomenon (Fig. 3 and Fig. 4). Color stripping can be achieved in both the reactive dyed fabrics with pH 3, Ozone concentration 45 g/m^3 ozone concentration and treatment time for 30 minutes. It is clear that still a small amount of color is present in the stripped fabric. Based on our previous study results, it could be possible to achieve more color removal by increasing the parameters like concentration of the ozone and also the treatment time while sticking to the acidic pH conditions [5].

3.2   Color Stripping % Results

We can see the color stripping % results in Table 1. We can see that, with the ozone based process conditions, we obtained around 94-95% decolorization.

Table 1: Color stripping % results

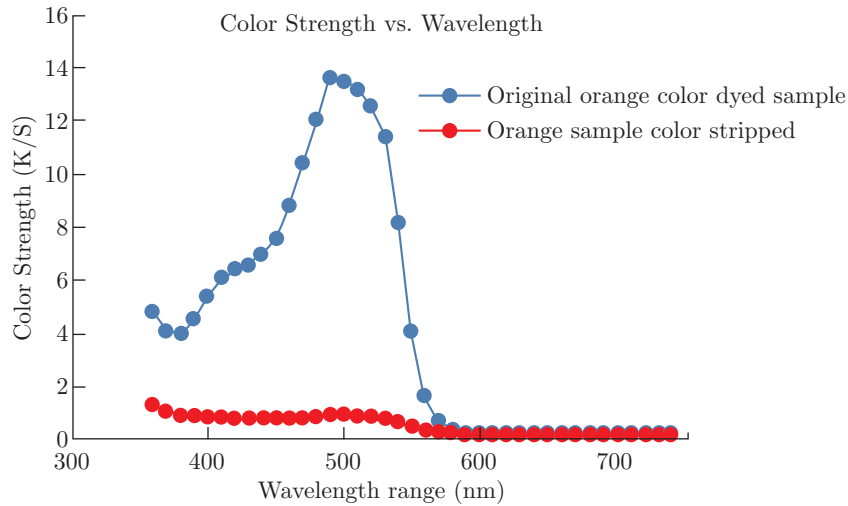| Sr. No .	Treatment	Color stripping %
1	Orange dyed stripped fabric	94
2	Pink dyed stripped fabric	95

Fig. 3: Wavelength vs. color strength graph for the color stripping of the orange dyed fabric
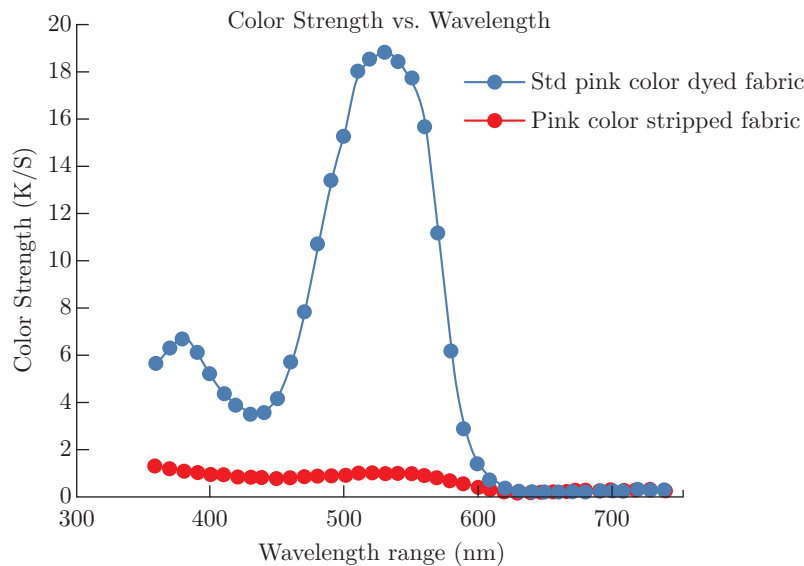

Fig. 4: Wavelength vs. color strength graph for the color stripping of the pink dyed fabric

3.3   Color Analysis of the Decolorization Samples

In Fig. 5, we can clearly see the fabric decolorizing directly through the photography of the stripped samples. We can see the effect of the ozonation process on the decolorization of the samples.

Additional color analysis was done with the help of CIELAB methodology. In both the decolorized samples, we can see the L* values increasing as compared to the dyed samples, which means that both the color stripped samples getting lighter due to the ozonation treatment. The color stripped sample is less redder and yellower as compared to the standard fabrics in both the cases. However, both the a* and b* values are not closer to the undyed RFD fabric. Hence, there is need to study more on the ozonation parameters to optimize the decolorization process.
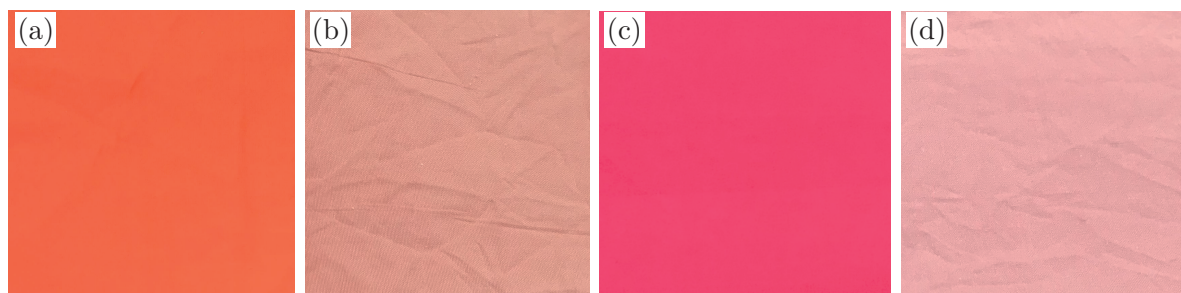
Fig. 5: Images of the standard dyed fabric and the dyed samples with the ozone treatment (a) Standard dyed fabric (Orange Everzol FC), (b) Color stripped treatment (Orange Everzol FC), (c) Standard dyed fabric (Rouge Everzol C-RB 133), (d) Color stripped treatment (Rouge Everzol C-RB 133)

Table 2: Colorimetric values (L*, a*, b*) values for the dyed reference, undyed RFD fabric and decolorization experiments

Sr. No.	Description	L*(D65)	a*(D65)	b*(D65)
1	Original orange color dyed sample	56.6	48.6	49.02
2	RFD fabric	83.76	-0.08	0.47
3	Orange sample color stripped	71.79	18.79	15.7
4	Original pink color dyed sample	38.61	55.62	6.38
5	RFD fabric	83.76	-0.08	0.47
6	Pink sample color stripped	65.13	18.36	4.31

3.4 Discussion

In our experimental study, the color removal at acidic pH would be associated with the more selective ozone molecular reaction [5]. There may be occurrence of two possible reaction mechanisms: indirect reaction involving the free radical mechanism and the direct reaction consisting of the attack by the molecular ozone. During the ozonation process, both of the reaction mechanisms exist simultaneously [8]. In recent study, ozonation in the aqueous solution of the Reactive Black 5 dye was modelled by Bilinska et al. (2017). At low pH, there is a direct attack by the ozone on the chromophoric azo groups $N = N$ [9].

4 Conclusion

Considering the results obtained the ozone assisted process gives good results for color stripping of the reactive dyed fabrics. Color stripping of almost around 94-95% was achieved in both the cases. Additional tests like the loss of the mechanical properties can be carried out. The process must be optimized with respect to the color stripping % and the tensile strength. We need to consider the other varied classes of the reactive dyes for the designed color stripping method. Also, it would be interesting to study the cost aspects of the designed process with respect to the conventional process.

Acknowledgement

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