AN ATTEMPT TO IMPROVE WASH FASTNESS OF RED DYES USING REAL TEXTILE WASTE WATER

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ABSTRACT: In this paper, the effectiveness of discarded wastewater from a cotton bleaching mill was evaluated for the removal of unfixed dyes from textile fabrics in order to achieve high level of fastness properties. Research was carried out on four selective reactive red dyes i.e. C.I. Reactive Red 194, C.I. Reactive Red 195, C.I. Reactive Red 231, and C.I. Reactive Red 141. Several fabrics were dyed using both conventional and new method under investigation, and comparison was made in terms of rubbing fastness, washing fastness, and colour difference properties. The results of experimental studies revealed that using discarded bleaching wastewater in the washing of red shades could be an efficient and cost-effective method which can attain fastness values of dyed samples up to an optimum value (4.5 – 5.0) without altering their colorimetric values (ΔL^*, ΔE^*).

Key words: Textile dyeing, Washing-off, Colour fastness, Wastewater, Bleaching

INTRODUCTION

Reactive dyes are most popular class among synthetic dyes. Their success is mainly attributed to the wide variety of brilliant colours, flexibility and ease of application, and all round fastness properties (Gulrajani et al., 2001; Lewis, 2011). Reactive dyes are most commonly used for dyeing of cellulosic and protein fibres, such as cotton and wool. The reactive parts of dye such as monochlorotriazine (MCT) or vinyl sulphone (VS) enable the dye to covalently bond with the –OH groups of cotton, with –NH2, –OH or –SH groups of wool, and with the –NH2 groups of Nylon (Koprivanac and Kusic, 2009).

These dyes suffer hydrolysis under highly alkaline conditions during fixation process which reduces the colour yield of dyes on fabric (Barkinshaw and Gandhi, 1997). Consequently, the dyed fabric is subjected to extensive washing and rinsing process at high temperature in order to remove hydrolyzed dyes which could otherwise jeopardize fastness properties of textile substrate (Broadbent *et al.,* 1998). This washing and rinsing regime comprises of several steps depending upon the type of dye and depth of shade used. Being a lengthy and water-intensive process, a large quantity of water is used during washing and rinsing process. This process is further assisted by chemicals such as anionic, non-ionic, and polyphosphate based detergents for the removal of unfixed dyes (Burkinshaw and Negrou, 2011). However, due to the increasing environmental awareness, use of phosphates in washing and rinsing has decreased significantly (Burkinshaw and Salihu, 2013).

In this study, efficiency of discarded bleaching wastewater to remove hydrolyzed dyes is evaluated. Since red dyes usually exhibit poor fastness properties, the research was focussed on this particular colour gamut of reactive dyes.

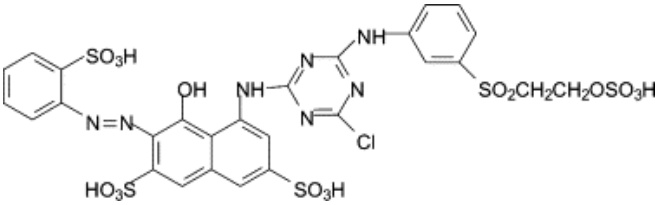
MATERIALS AND METHODS

Bleaching wastewater samples (10 litres each) were collected from the final discharge of 4 similar textile factories, located in Raiwind industrial area, and examined for physical and chemical characteristics (Table 1). No special statistical technique was required in this study due to the nature of investigation and the limited number of wastewater sources.

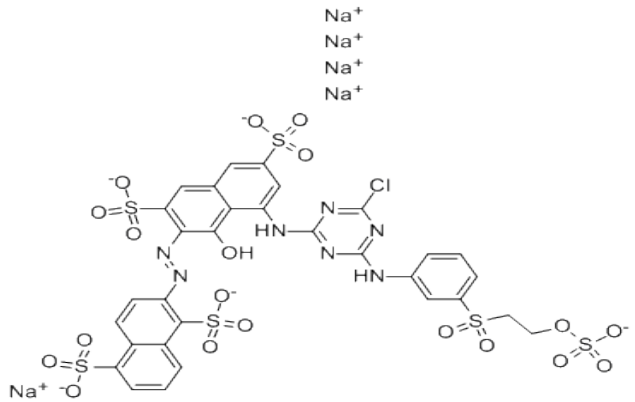
Table-1. Showing characteristics of discarded bleaching wastewater

Parameters	Values
pH	12.3
Conductivity	6790 µS/cm
Chemical oxygen demand (COD)	2895 ppm
Total dissolved solids (TDS)	3390 ppm
Hydrogen peroxide (H_2O_2) concentration	104 ppm
Alkalinity	0.48 g/L
Colour	light yellow

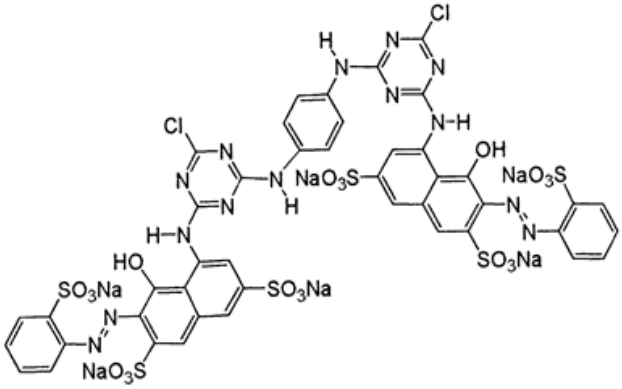
The fabric used in study was 100% cotton knitted fabric with 200 GSM. Four red dyes, C.I. Reactive Red 194, C.I. Reactive Red 195, C.I. Reactive Red 231, and C.I. Reactive Red 141, were used in the experimental work. Chemical structures of these dyes are displayed in Figure-1.



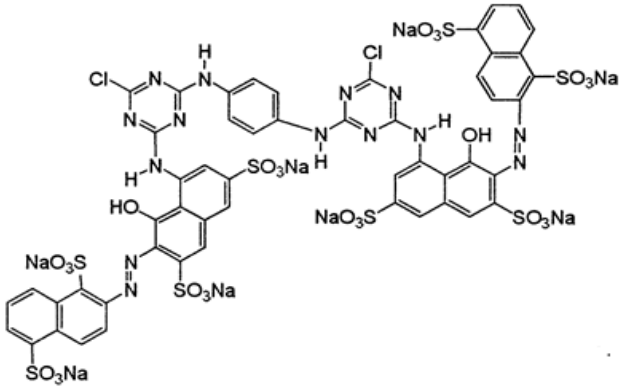
a) C.I. Reactive Red 194



b) C.I. Reactive Red 195



c) C.I. Reactive Red 231



d) C.I. Reactive Red 141

Figure-1 Showing chemical structures of red dyes

Sodium chloride (NaCl) and sodium carbonate (Na_2CO_3) used in dyeing were of commercial grade.

Dyeing and washing procedure: Dyeing was carried out on 10 gram fabric sample using liquor ratio of 1:10 at 60°C and 80°C temperature for bifunctional (BF) and monochlorotrizane (MCT) dyes, respectively. A darker depth of shade of 6% on weight of the fibres (o.w.f) was selected for colour strength. At the end of dyeing, dyed samples were cut into 4 equal swatches. First swatch was regarded as standard and treated with conventional wash-off process, which included rinsing, neutralization (30°C), warm wash (50°C), hot wash (80°C), soaping (detergent + 90°C), warm wash (50°C), and final rinsing steps (10 minutes each). The remaining three swatches were subjected to the new wash-off process using discarded wastewater, and employing three different temperatures. After cold rinsing and neutralization steps as in conventional process, 2nd swatch of fabric was washed with one hot wash consisting of bleaching wastewater at 80°C. The 3rd and 4th swatches were given 2 and 3 hot washes (80°C) using discarded wastewater. Afterwards, washed-off samples were dried and subjected to colour difference and fastness testing.

Evaluation of colour difference and fastness properties: Colour difference values between standard and those washed-off with wastewater were determined by using Datacolor Spectroflash 600 spectrophotometer. Fabric was folded twice and average of four readings was calculated for each sample (Barkinshaw and Salihu, 2013). The colour fastness to staining and rubbing were assessed using Test Methods AATCC 61-2001 and AATCC 8-2001 (AATCC, 2001). Staining was evaluated using spectrophotometer according to AATCC Evaluation Procedure 7. The rating grade used was 1 (poor) to 5 (excellent).

RESULTS AND DISCUSSION

Effects of wash-off on fastness properties: A comparison of fastness properties of four red reactive dyes has been presented in Table 2. This study focussed on red dyes because red dyes have been extensively investigated by several researchers (Burkinshaw and Jeong, 2008; Akalin *et al*., 2004; Burkinshaw and Katsarelias, 1997) for the improvement of fastness properties. The overall results revealed that wash-off using discarded wastewater imparted similar or improved fastness ratings than those of standard wash-off. The

colour fastness results pertaining to C.I. Reactive Red 194 showed that all the three wash-offs using bleaching wastewater provided excellent fastness results in the range of 4.5 to 5.0. Wet crocking and staining results obtained were found to be half degree better than those of standard wash-off. In case of C.I. Reactive Red 195, C.I. Reactive Red 231, and C.I. Reactive Red 141, similar trend was observed, and staining results ranged between 4.5 and 5. Similar studies (Wang and Wu, 2009; Xie *et al*., 2014; Wang and Li, 2013; Wang *et al*., 2009) reported unsatisfactory wet fastness results of red dyes in conventional wash-off procedure because even a small quantity of red dye was visible due to its higher wavelength ($\lambda \approx 700$). Even in industrial practices, it was generally observed that red dyed fabric frequently failed in washing fastness properties and dyers had to tackle this quality issue by using special dyes (Rizk *et al*., 2015) or they had to apply special chemicals such as cationic fixing agents (Awais *et al*., 2015).

Influence of wash-off on colorimetric values: Colorimetric values always provide useful information to researchers interested in the evaluation of colour and shade change after a particular chemical or physical treatment (Senthilkumar *et al*., 2011; Garrech and Ncib, 2009). Colour difference values in terms of lightness/darkness (ΔL^*) and magnitude of total colour difference (ΔE^*) of dyed samples under investigation were assessed against the standard samples washed-off with conventional method. Figures 2 and 3 display the values of ΔL^* and ΔL^*, respectively. If the ΔL^* value was positive, it means shade of the sample was lighter than the shade of the standard, and if the value was negative then it was considered a darker shade. In case of C.I. Reactive Red 194, the 1st wash yielded a dark shade (-0.67), however, the darkness level decreased gradually in 2nd wash (-0.29) and 3rd wash (-0.11) because more washes removed more hydrolyzed dyes from dyed fabric samples. The rest of the dyes i.e. C.I. Reactive Red 195, C.I. Reactive Red 231, and C.I. Reactive Red 141 showed similar trend. Results shown in Figure 3 indicated that the total colour difference (ΔE^*) values increased with increasing number of washes. These results could be attributed to the repeated action of wastewater in removing surplus dyes from samples, and consequently, altering the hue of final shade. These results clearly correlated with the finding of similar investigations of (Burkinshaw and Son, 2006; Gotoh and Harayama, 2013). However, in all the cases, samples subjected to 1st and 2nd washing while using discarded wastewater were found be commercially acceptable because ΔE^* values were found to be closer to 1.0, and these results were widely considered as passed standards (Menon and Calvango, 2011; Gozalo-Diaz *et al*., 2007).

Table-2. Showing comparison of wash fastness properties of standard and samples

	No. of wash	Crocking		Colour staining			Change of shade
		Dry	Wet	Cotton	Nylon	Polyester	
C.I. Reactive Red 194							
Reference	-	5	4.5	4.5	5	5	-
Sample-1	1st	5	5	4.5	5	5	4.5
Sample-2	2nd	5	5	5	5	5	4
Sample-3	3rd	5	5	5	5	5	4
C.I. Reactive Red 195							
Reference	-	5	4.5	4.5	4.5	5	-
Sample-1	1st	5	4.5	5	5	5	5
Sample-2	2nd	5	5	5	5	5	4.5
Sample-3	3rd	5	5	5	5	5	4
C.I. Reactive Red 231							
Reference	-	5	5	4.5	5	5	-
Sample-1	1st	5	5	4.5	5	5	4.5
Sample-2	2nd	5	5	4.5	5	5	4
Sample-3	3rd	5	5	4	5	5	3.5
C.I. Reactive Red 141							
Reference	-	5	4.5	4.5	5	5	-
Sample-1	1st	5	4.5	5	5	5	5.0
Sample-2	2nd	5	5	5	5	5	4
Sample-3	3rd	5	5	5	5	5	3.5

Figure-2: Lightness/Darkness (ΔL^*) values of dyes samples

Figure-3: Total colour difference (ΔE^*) values of dyes samples

Conclusion: A new, efficient, and environment friendly wash-off method for dark shade dyeing was investigated where in only discarded wastewater was utilized instead of using fresh water and detergents. In this study, it was observed that removal of hydrolyzed dyes took place effectively even in 1st wash using wastewater. Further washes (2nd and 3rd) did improve the fastness levels particularly in wet crocking and staining to cotton, however, perceived change of colour difference observed in 2nd and 3rd washing, compared to the fastness levels of conventionally washed samples, similar or better level of fastness was achieved in samples washed-off using discarded bleaching wastewater. This study concludes that the use of discarded wastewater in washing-off steps of reactive dyeing is a viable alternative to the conventional method.

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