RECYCLING OF WASHING AND RINSING TEXTILE WASTE WATER IN COTTON DYEING FOLLOWING AN O_3 TREATMENT

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ABSTRACT: The present study evaluated the potential of reusing washing and rinsing wastewater after it was treated with ozone (O_3). Experimental results showed that 95, 98, and 100% colour removal efficiencies were achieved in a composite wastewater sample at 10, 20, and 30 minutes of O_3 treatment, respectively. Chemical oxygen demand (COD) and pH values were also found to be decreasing with increasing treatment time. Cotton dyeings were then carried out in O_3 decolourized washing and rinsing wastewater using three widely used commercial reactive dyes. Dyedfabric samples were subjected to quality testing in terms of washing, rubbing, and colour difference properties. This study concluded that ozonation was an efficient method for the treatment of textile washing and rinsing wastewater. The treated wastewater was then successfully reused in cotton dyeing without deteriorating the dyeing quality. This method also proved to be environmentally friendly because it did not consume any fresh water and used only discarded wastewater, hence reducing pollution load significantly.

Keywords: Reactive dyeing, Recycling Washing and rinsing, Ozone, fastness, Wastewater.

INTRODUCTION

Textile production is one of the main industrial sectors of Pakistan. Textile industries are responsible for the discharge of large quantity of wastewater into natural waterways due to high consumption of water in textile dyeing, finishing, printing, and associated industries. A typical cotton dyeing process using reactive dyes consumes around 120-280 litres of water for one kg of textile material (Schoeberl*et al.*, 2005). Within the dyeing process, the wash-off and rinsing treatment typically accounts for a major portion (50%) of the total dyeing cost and effluent load (Burkinshaw and Kabambe, 2009).

The escalating cost of energy, water, wastewater treatment coupled with mounting environmental pressure force textile factories to look for new methods to save waterand energy.There are numerous applied methods for the treatment of textile wastewaters,involving physical, chemical, biological methods and several possible combinations of these(Wu *et al.,* 2008). Important methods include coagulation/flocculation, sedimentation/precipitation, filtration /membrane technologies, and conventional biological treatments such as activated sludge, trickling filter, and lagoon systems. The biggest disadvantage of these treatment methods is that they are neither fullyefficient nor economically viable due to the requirement of large land areas (Kumar *et al.*, 2011)

A number of researchers have reported that Ozone (O_3)treatment is very efficient in removing colour and organic pollutants from textile effluents (Hao et al., 2000; Selcuk, 2005; Eren*et al.,* 2012). Due to very high oxidation potential of ozone gas (2.07 V), it is capable to break down majority of organic contaminants including textile dyes (Strickland and Perkins, 1995) without producing any sludge or toxic by-products (Gahr*et al.,* 1994). Ozone decomposition in water had been investigated by Hewes and Davison (1971) and proposed the following mechanism:

$$O_3 + H_2O \longrightarrow HO_3^+ + OH^-$$
$$HO_3^+ + OH^- \longrightarrow 2HO_2$$
$$O_3 + HO_2 \longrightarrow HO\cdot + 2O_2$$
$$HO\cdot + HO_2 \longrightarrow H_2O\cdot + O_2$$

In this study, segregated washing and rinsing wastewater from a local textile factory was collected and given a laboratory scale ozone treatment for the removal of colour and chemical oxygen demand (COD), and then reused in several reactive dyeings. The key characteristics of dyed fabrics (i.e., washing fastness, rubbing fastness, change of shade, and colour difference properties) were determined and compared with those of conventionally dyed fabric samples. The reuse of washing and rinsing wastewater after its treatment with ozone showed acceptable results, and it seems to be an alternative approach that can offer savings of precious water.

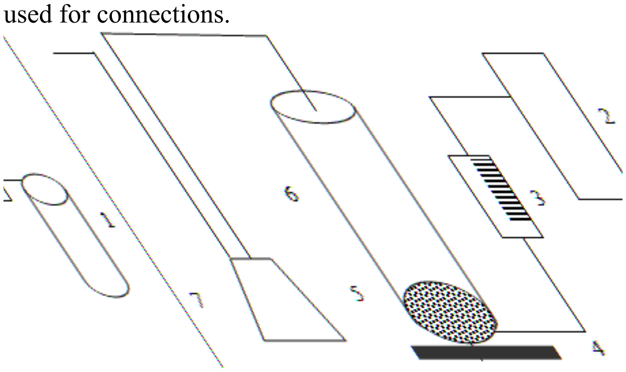
MATERIALS AND METHODS

Wastewater sampling and analysis: Washing and rinsing process was carried out almost in alltypes of dyeing. Wastewater generated in these processes was collected directly from the discharge of several dyeing machines, and a composite sample of wastewater was prepared. A laboratory analysis of this sample showed the following physical and chemicalpropertiesas shown in Table 1.

Table-1.Showing characteristics of textile washing and rinsing wastewater

Constituents	Concentration
Chemical oxygen demand (COD)	112 ppm
Biological oxygen demand (BOD)	9 ppm
Chlorides	5 ppm
pH	8.1
Conductivity	74 µS/cm
Colour	light grey

Ozone decolorization: Washing and rinsing wastewater was subjected to ozone treatment using a laboratory setup as shown in Figure-1. It was comprised consisting of an O_2 concentrator (model M5C5, Nidek Products), O_3 generator (model L10G, Farady), bubble column reactor and a diffuser stone as shown in Figure-1. Ozone generator was capable to produce up to 1 g /hr ozone. Ozone output and flow rate was kept at 1000 mg/hr and 3 LPM, respectively, to maintain ozone concentrationat 5.5mg/L. The reactor was consisted of 40cm long column of 6.0cm diameter (internal), fixed with a diffuser stone at the bottom for a homogeneous distribution of O_3 gas into the wastewater. Ozone resistant Teflon tubing was used for connections.



1-Oxygen Concentrator 2- Ozone Generator 3- Flow meter
4-Stirrer 5-Stone diffuser 6- Reactor 7-Trap solution (KI)

Figure-1.Showing laboratory set-up for O_3 application

Substrate, dyes, chemicals, and dyeing process:A 100% cotton fabric (single jersey) made with 24 single carded yarn (180 GSM) was used in this study. Three most widely used bi-functional dyes namely,Sumifix Supra Yellow 3RF, Sumifix Supra Brilliant Red 2BF, and Sumifix Supra Blue BRF were used in the experimental work.General chemical structure of all three dyes is shown in Figure-2.

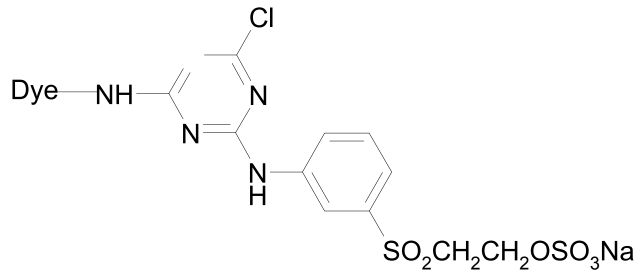


Figure-2:Showing general chemical structure of bi-functional dyes

Dyeing and testingprocedures: Pre-bleached fabric samples (5 g) were dyed in a sealed stainless steel dyeing pots of 300 ml capacity, housed in a laboratory-scale dyeing machine (AHIBA NUANCE, Datacolor), using a liquor ratio of 10:1. The dyeing procedure for the dyesis exhibited in Figure-3. At the end of dyeing, fabric samples were removed, rinsedthoroughly in warm water and dried in the open air. Afterwards, fastnesses of the dyed samples to washing and to wet and dry rubbings were determined in accordance with ISO 105 C06 method (A1S) and ISO 105-X12, respectively.

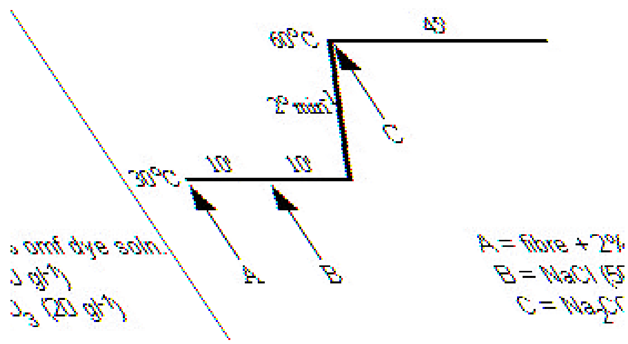


Figure-3: Showing dyeing procedure used in the study

RESULTS AND DISCUSSION

Decolorization and COD removal: The colour removal efficiency of ozone for composite wastewater sample consisted of spent washing and rinsing drains (Table-2). It can be seen that O_3wasextremely effective for decolourisation of wastewater, with colour removal efficiency higher than 90% in the first 10 minutes. Treatment of 30 minutes proved to be sufficient because it yielded 100% reduction of colour. The results showed that colour and COD removal was mainly dependent on O_3 treatment time. In all cases, it was observed that the pH of wastewater under investigation decreased (9.2 to 7.6) during the O_3application. Other researchers have reported the similar results and attributed this phenomenon to the formation of acidic by-products that cause a decrease in pH (Shu and Huang, 1995; Soares*et* *al.,* 2006). An increase in conductivity was also noticed,which was due to the degradation of dye molecules in wastewater (Khare*et al.,* 2007).

Table-2.Showing process conditions and efficiency of O_3 application

Ozonation Period (min.)	Ozone Production (mg/hr)	Ozone Flow (LPM)	Ozone Dose (mg/m)	Ozone Concentration (mg/L)	COD (mg/L)	Conductivity (µS/cm)	pH	Color removal (%)
0	1000	3	16.66	5.55	112	8	9.2	-
10					47	11	8.8	95
20					20	18	7.9	98
30					5	19	7.6	100

Evaluation of colour differences: The colour difference values i.e. ΔL^*, Δc^*, Δh^* *and* ΔE^* between standard fabric (dyed in fresh water) and samples (dyed in O_3 treated washing and rinsing wastewater) has been summarized in Table-3. The results indicatedthat total colour difference (ΔE^*) in all three dyeing was found to be ≤ 1.0. This cut-off value was considered a commercially acceptable tolerance level (Fruhwirth*et al.,* 2002). The results (ΔE^* = 0.28) of Sumifix Supra Yellow 3RF dyeing confirmed that final shade of the sample dyed using washing wastewater was comparable to that of reference. In case of Sumifix Supra Brilliant Red 2BF, negligible colour differences in lightness *(*ΔL^*=-0.18*)*, chroma*(*Δc^*= -0.31), hue (Δh^* = 0.12), and total difference (ΔE^*=0.47) showed an identical colour match. For Sumifix Supra Blue BRF, similar trend was observed and lower colour difference valuesof ΔL*, Δc*, Δh*, and ΔE^* suggested no perceived colour difference between reference and sample dyed in treated washing and rinsing wastewater.

Table-3. Showing colour difference values of standard and samples dyed in ozone treated wastewater

Dyes	Colour difference values					
	ΔL^*	Δa^*	Δb^*	Δc^*	Δh^*	ΔE^*
Sumifix Supra Yellow 3RF	0.11	0.17	-0.10	0.07	0.22	0.28
Sumifix Supra Brilliant Red 2BF	-0.18	0.29	0.17	-0.31	0.12	0.47
Sumifix Supra Blue BRF	-0.20	0.40	-0.37	-0.47	-0.21	0.75

Evaluation of colour fastness properties: The comparison of fastness properties of dyed samples revealed that fabric samples dyed in O_3 treated washing and rinsing wastewater possessed similar fastness ratingscompared with standard dyed samples have been presented in Table-4. The colour fastness resultswith regard to SumifixSupra Yellow 3RFdye showedgood results in the range of 4.5 to 5.0, which were considered acceptable in the industry (Iftikhar*et al.,* 2001).ForSumifix Supra Brilliant Red 2BF and Sumifix Supra Blue BRF dyes, all fastness results i.e. dry and wet rubbing, staining to cotton, nylon, and polyester were found to be excellent and comparable to those of standard dyed samples.

Table-4.Showing wash fastness properties of reference and samplesdyed in ozone treated wastewater

Dyes	Rubbing Fastness		Multi-fibre staining			Shade Change
	Dry	Wet	Cotton	Nylon	Polyester	
Reference	5	4.5	4.5	5	5	-
Sumifix Supra Yellow 3RF	5	5	5	5	5	5
Sumifix Supra Brilliant Red 2BF	5	4.5	4.5	5	5	4.5
Sumifix Supra Blue BRF	5	4.5	4.5	5	5	4.5

Conclusion: The present study explored an alternative method of dyeing cotton wherein O_3 treated wastewater from textile washing and rinsing was used, instead of using fresh raw water. Besides reducing pH and chemical oxygen demand (COD) significantly, ozone gas was found to be capable of decolorizing wastewater up to 100% in just 30 minutes of treatment time. Several cotton dyeingsusing O_3 decolourized wastewater were carried out, and commercially acceptable results in terms of washing, rubbing, and colour difference properties were achieved.This study concluded that ozonationwas an efficient method for the treatment of washing and rinsing wastewater.

Acknowledgement: The authors wish to thank the Committee for Research Projects constituted by the Vice Chancellor of the Punjab University for financially supporting this experimental work.

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