Indian Journal of Fibre & Textile Research
Vol 44, March 2019, pp. 107-112

A water saving approach in textile finishing by reusing batch-washing wastewater

Ahmet Çay[1,a], Serdin Çelik[2], Ayhan Yardım[1] & Benhür Selışık[1]

[1]Department of Textile Engineering, Faculty of Engineering, Ege University, 35100 Bornova, İzmir, Turkey
[2]Ekoten Tekstil San. ve Tic. A.Ş., Torbalı, İzmir, Turkey

Received 24 February 2017; revised received and accepted 3 August 2017

This study proposes a water saving approach through the reuse of washing wastewater without draining. The final bath (neutralisation bath) of the washing processes for cleaning purposes is not drained but reused in the first step of the next washing process. All the practises are carried out in plant scale and by using actual operational data. It is found that 10-30% water saving can be obtained in washing processes without any investment cost. It is also observed that the method does not have considerable negative effect on the quality of the fabric.

Keywords: Batch washing, Cotton, Polyester, Textile finishing, Viscose, Water saving

1 Introduction

Consumption of textile materials is gradually increasing due to the growth in world population, improvement in quality of life and inclusion of fashion industry on diversity. The worldwide pressure on environmental issues is also steadily increasing[1], thus making sustainable production practices a necessity. When considering the sustainability in textile industry, high water and energy consumption and the resultant waste emissions are the biggest obstacles in sustainable production. Within the textile industry, textile finishing is one of the most water intensive sub-sectors due to high amount of water consumption in wet processes such as pre-treatment, dyeing and washing. Over the last few decades, many textile finishing machines have been developed with short liquor-to-material ratio to reduce water consumption[2]. Hence, due to both environmental considerations and cost factors, efforts have been made for minimization of water consumption. Specific water consumption in textile finishing mills varies between 25 L/kg and 200 L/kg, depending on the type of material and process used[3]. Achievable minimum specific water consumption levels were reported by European IPPC (Integrated Pollution Prevention and Control) Bureau[4] as 70-120 L/kg for yarn and knitted fabric finishing, and 50-100 L/kg (< 200 L/kg for some cases) for woven fabric finishing. However, more than 200 L/kg (even more than 600 L/kg) specific water consumption values have also been reported[4]. Although the wastewater from textile finishing processes can be treated and reused in various advanced treatment methods[5-10], the best strategy for the reduction in water consumption should be the reduction of wastewater generation. Appropriate process optimization possibilities, detection & prevention of water leakages, and reusability of process water without the need for additional processing should be assessed in the first stage. On this account, it will be possible to achieve high water savings without a significant investment and operating costs.

Jiang *et al.*[11] proposed an algorithm to reduce the production time and water consumption in textile dyeing plants. They observed that the arrangement of the production sequence from light to dark colour in a production line and the combined processing of fabrics of the same colour reduced the water consumption by 20-30%. Alkaya and Demirer[12] presented a case study from a woven finishing plant on the reduction of water, energy, chemical consumption and emissions. They have shown that the water consumption was reduced by the reuse of stenter and singeing cooling water, by use of drain and fill washing instead of overflow, and by renovation of ion-exchange system, water pipelines and equipments. Ozturk *et al.*[13] have investigated the cleaner production possibilities in an acrylic/wool dyeing plant. They found that a considerable water saving was possible through the reuse of process

[a]Corresponding author.
E-mail: ahmet.cay@ege.edu.tr

wastewater in the same or other processes or in tank washings as it is or after mixing with clean water, depending on the wastewater quality. In the study of Ozturk *et al.*[14], a cotton/polyester fabric dyeing plant has been analysed in terms of water and chemical saving possibilities. Wastewater from regeneration and dyeing-finishing processes was found to be reusable in facility cleaning and dyeing-finishing processes directly or after an appropriate advanced treatment according to the waste water quality. Kiran-Ciliz[15] reported that water saving can be achieved by the optimisation of back-washing time in regeneration process through the measurement of hardness and by omitting last stage of rinsing in finishing processes.

Studies on direct reuse of process wastewater have also been reported in the literature. Shaikh *et al.*[16] reported that the reuse of hydrogen peroxide bleaching of wastewater in wash-off step of reactive dyeing is possible with similar colour fastness and minimal colour difference. In another study of Osman *et al.*[17], the reuse of washing water for the pre-treatment process in yarn dyeing plants has been reported. It has been found that rinsing wastewater applied before dyeing can be directly used for scouring and bleaching. Yang and Xu[18] have investigated the use of reactive dyeing wastewater for nylon and wool dyeing with very good wash and rub colour fastness. Sonaje and Chougule[19] have reported that the multiple use of scouring and bleaching baths is also possible for water and chemical saving. Similarly, Harane and Adivarekar[20] have investigated that separate pre-treatment baths can be reused multiple times without replenishing water and chemicals with satisfactory fabric properties. Chattopadhyay *et al.*[21] have examined the reusability of reactive dye baths in jute dyeing. It has been found that the two-step two-bath method of reactive dyeing, where exhaustion and fixation step are separated, is most ideal for reuse of dye bath. Erdumlu *et al.*[22] have reported that the wastewater from different finishing processes can be reused without being totally purified but only after basic treatments such as filtering, airing, *p*H regulating and ion-exchange.

While it is easier to reuse water in continuous processes, batch processes have various difficulties. First of all, due to discontinuous character and process variability, water draining and filling times of the machines are not simultaneous. Therefore, an additional storage tank is needed to collect waste streams to be reused. Additionally, the reuse of dye baths, in particular, requires careful measurement and control. Otherwise, it is very likely that quality problems will emerge. In this study, washing processes are taken into account and the reuse of final washing (neutralisation) wastewater in the first step of next washing process without draining the bath is investigated.

2 Materials and Methods

2.1 System Description and Design Phase

The water saving practices were carried out in a textile finishing plant by using actual operational data. Both batch (jet-dyeing line) and continuous (pad-batch line) finishing methods are used in the finishing plant. In order to determine the reusability of process water, operating processes of the plant were examined at first. Low colour and chemical content was selected as the main criteria for reusability of wastewater. Since the pad-batch liquors are highly concentrated, they restrict the reuse of the wastewater. Moreover, as the counter-current washing is applied in the continuous washing machine after the pad-batch, there is also little chance of reuse here. Therefore, jet-dyeing line (batch-wise finishing processes) was selected for this application. Jet-dyeing line is operated by an automation system with nearly 250 dyeing/finishing recipe programs. All the process parameters such as temperature, time, chemical type and concentration can be changed and adjusted automatically. Qualitative analysis of the programs shows that the processes with the least colour and chemical load are the washing processes. Washing processes are divided into post-dyeing washings and washing for cleaning purposes. Post-dyeing (or any post-process) washing is applied to remove unfixed dye (or any finishing chemical) from fabrics which, in general, have high levels of colour. Washing for cleaning purposes are carried out to clean yarn dyed (or previously dyed) fabrics through the removal of dust, oil, etc. Washing process for cleaning is classified in three groups depending on the types of fabric, viz cotton washing (for cotton and cotton blends), viscose washing (for viscose and viscose blends) and polyester washing. It was qualitatively determined that some of the wastewater in cotton and viscose washing was clean enough to be reused. Thus, it was planned to focus only on the cotton and viscose washing process within the scope of the study, as polyester washing in the company was very limited.

The design steps of the proposed method for the reuse of washing wastewater are schematized in Fig. 1.

Each washing process consists of two consecutive steps. In the first step, wastewater includes washing agents or enzyme/soda, thus the reuse of these water is not possible. The second stage might be softening or neutralisation. Softening wastewater cannot be reused, but neutralisation bath include only acid for *p*H adjustment and is thought to have a potential for reusing. For this reason, the reuse of neutralisation wastewater in the first step of the washing process has been investigated. In the presented method, after neutralisation, the fabric is removed, the neutralisation bath is not drained out but reused in the first step of the next wash.

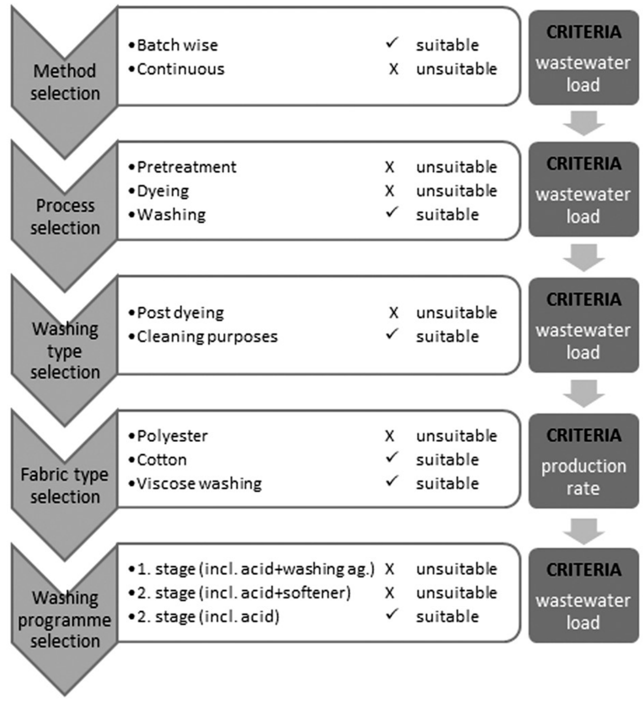

Fig. 1 — Design phases of the method presented for the reuse of wastewater

2.2 Fabric Tests

Washing processes were usually carried out in a separate machine (jet dyeing machine, 800 kg capacity), and therefore the practices and programming for the reuse of washing water were easily applied. To avoid disturbance and to distinguish it from the standard washing processes, the washing processes (in which the waste water was reused) are encoded as R-washing, and the relevant samples as R-washed samples. It was necessary to establish whether reuse of washing water affects the quality of the fabric. For this reason, the colour values and wash/rub fastness of Standard and R-washed samples were compared.

Colour measurements of the fabrics were carried out according to CIELab colour space using Minolta 3600d spectrophotometer with D65/10^o. In striped fabrics, the whiteness index of white parts was measured. The effects of reused washing water on the colour of the washing baths was also examined using a UV-Vis spectrophotometer (Perkin Elmer, Lambda 25).

Wash fastness tests of fabrics were carried out according to BS EN ISO 105 CO6 (A1S) standard. Accordingly, 10 steel balls were added to a 150 mL bath containing 4 g/L Ece-b detergent, and the samples with multifibre were washed at 40 °C for 30 min. The samples were dried at room temperature after washing and then the staining of multifibre evaluated on a gray scale (1 worst - 5 best). Also, colour fastness to rubbing (dry and wet) was tested according to ISO test method 105-X12.

3 Results and Discussion

The possibility of the reuse of neutralisation wastewater in the first step of batch-wise washing processes has been investigated. For this purpose, the neutralisation bath is not drained out after the process and reused for the next washing. It is useful to note here that some of the water of the neutralisation bath is removed by the machine with the fabric. The amount of this removed water differs, based on the fabric structure and the type of fibre. Hereunder, the application results for viscose and cotton washing are reported.

3.1 Reuse of Viscose Washing Wastewater in Viscose Washing Process

In this set of application, the neutralisation wastewater of standard viscose washing was reused for the first step (second lot of the same fabric) of viscose washing. The results for viscose washing trials are shown in Table 1.

In the first trial, grey coloured, viscose blend single jersey fabric is used. Through unloading of the last washing water of the previous batch, about 1295 L of water was saved for the next lot washing. This means about 13% water saving for a total washing process. Table 1 shows no difference between Standard and R-washed samples in terms of colour values and rub fastness. Wash fastness is found to decrease by half points (from 5 to 4-5) in R-washing.

In order to demonstrate the repeatability of the method, different types of fabrics in different colours are also tested (claret red lacoste, black/white striped single jersey and grey/white striped single jersey). At this stage of the study, especially the fabrics with white stripes are chosen. Since reused neutralisation water is slightly coloured, there is a risk of staining on white stripes. Figure 2 illustrates the absorbance values of the washing waters for claret red and grey/white striped fabrics. It is observed that by the reuse of the neutralisation wastewater coming from the previous lot, the colour of the washing bath increases [Fig 2(a)]. Moreover, at the end of the washing process, the colour of the wastewater is higher for R-washing as compared to that for standard washing. However, this increase in colour of the washing baths does not affect the fastness values of the samples (Table 1). It is observed that the whiteness index is similar for Standard and R-washing, which proves that there is no staining. Moreover, wash and rub fastness are not affected by the reuse of wastewater. This categorically explains that, in Standard washing process, the water was underutilised and drained without taking as much impurity as it can get. Thus, by the reuse of the wastewater, more efficient use of washing water was obtained, which also helps in water saving. It should also be mentioned that all the R-washed samples passed through the quality control tests of the plant. The test results show that it is possible to reuse the neutralisation wastewater of the viscose washing process, in order to save water.

3.2 Three Consecutive Viscose Washing

The increase in colour of washing baths has been observed through the reuse of wastewater collected from previous process. Thus, in order to investigate whether the fastness of the fabrics will be affected if the water reuse is applied continuously, three viscose washing processes of viscose blend grey fabrics are carried out consecutively. Each process reused the wastewater of the last step (neutralisation) of previous process. By the application of consecutive R-washing, 1200 L (14.8 %) of water is saved in the first and 2100 L (21.5 %) of water are saved in the second R-washing. It is observed that wash and rub fastness values of fabrics subjected to R-washing is high and close to each other (wash fastness of first and second R-washed samples are found to be 5/5/5/5/5/5 and 5/5/4-5/5/4-5/5, and rub fastness (dry/wet) to be 4-5/2-3 and 5/3 respectively. There is no colour difference between the lots (ΔE – colour difference between first and second R-washed samples are found to be 0.25). All the fabrics subjected to R-washing were passed through quality control. The results indicate that the reuse of neutralisation wastewater can be applied in

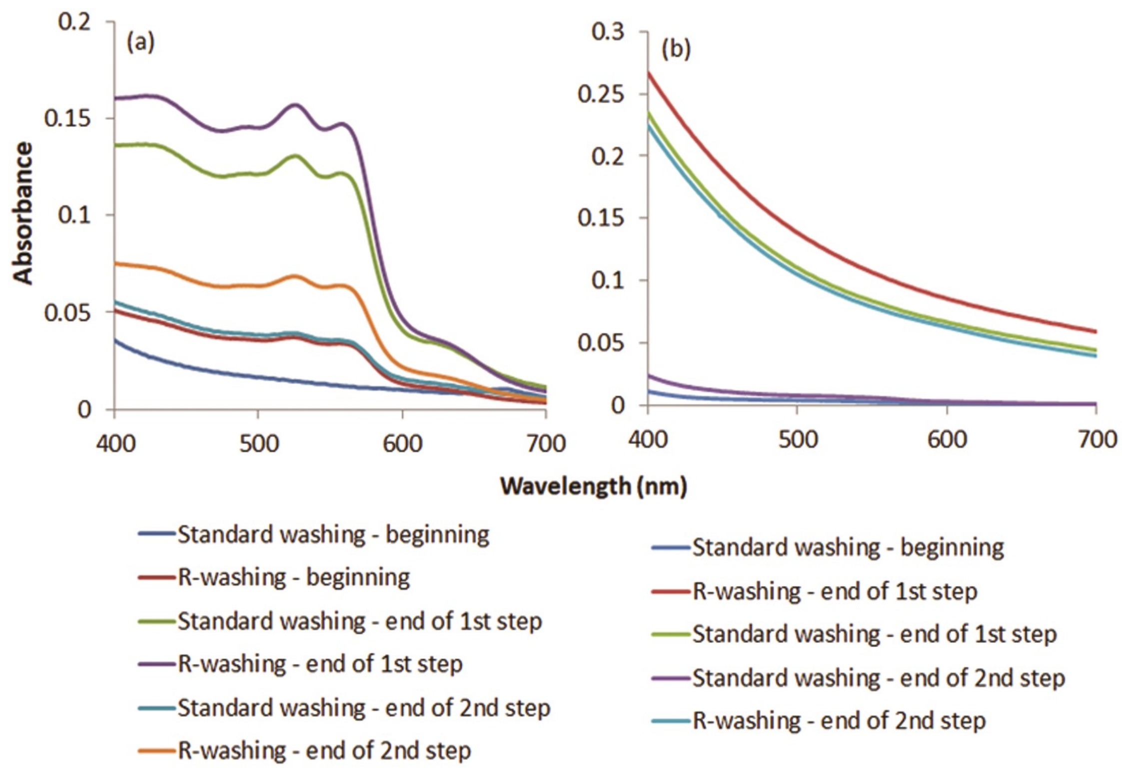

Fig. 2 — Absorbance values of washing water in viscose washing process for (a) claret red and (b) grey/white striped fabrics

Table 1 — Comparison of standard and R-washing for viscose washing processes

Fabric	Colour	Process	Wash fastness (WO/PAC/PES/PA/CO/CA)[a]	Rub fastness dry/wet	Whiteness index[b]	Colour difference (ΔE)
Viscose blend	Grey	Standard	5/5/5/5/5/5	4-5/2-3	-	0.22
		R-washing	5/4-5/4-5/4-5/4-5/4-5	4-5/3	-	
Viscose blend	Claret red	Standard	5/5/5/5/5/5	5/3-4	-	0.34
		R-washing	5/5/5/5/5/5	5/3-4	-	
Viscose blend	Grey/white striped	Standard	5/5/5/5/5/5	5/3-4	45.05	0.99
		R-washing	5/5/5/5/5/5	5/3-4	40.25	
Viscose blend	Black/white striped	Standard	5/5/5/5/5/5	5/5	46.62	0.49
		R-washing	5/5/5/5/5/5	5/5	48.60	

[a]Fibre content of standard multifibre fabric used in wash fastness test (WO-wool, PAC-acryline, PES-polyester, PA-polyamide, CO-cotton, and CA- cellulose acetate). [b]Whiteness index was only tested for striped fabrics to investigate the staining of white stripes.

Table 2 — Reuse of cotton washing wastewater in the next cotton or viscose washing

Process	Sample	Wash fastness (WO/PAC/PES/PA/CO/CA)[a]	Rub fastness dry/wet	Colour difference (ΔE)	Water saving, %
Standard	Cotton blend	5/5/5/5/5/5	5/5	0.77	10.9
R-washing	Cotton blend	5/5/5/5/5/5	5/5		
Standard	Cotton blend	5/5/5/5/5/5	4-5/2-3	0.1	29.5
R-washing	Viscose blend	5/4-5/4-5/4-5/4-5/4-5	4-5/2-3		

[a]Fibre content of standard multifibre fabric used in wash fastness test.

succession and approximately 15-20% of water can be saved in each washing process.

3.3 Reuse of Cotton Washing Wastewater in Viscose or Cotton Washing Process

In order to investigate the flexibility of the presented method, the wastewater from the last step (neutralisation) of cotton washing process has been reused and studied. Table 2 shows the data for consecutive cotton→cotton and cotton→viscose washing. In the first trial, wastewater from cotton washing process is reused in the first step of viscose washing. For viscose washing, viscose blend single jersey fabric (the same sample reported in Table 1) is used and this R-washed sample is compared with standard washed one. The colour difference between R-washed and standard washed viscose sample is calculated as 0.1. R-washed viscose sample has the same rub fastness as that of the standard sample, while the wash fastness decreases by half points. It is shown that approximately 30% of water saving can be obtained.

In the second trial, wastewater from cotton washing process is reused again in the first step of cotton washing for the second lot of the same fabric. Wash and rub fastness of standard washed and R-washed cotton samples are found to be the same. A relatively higher colour difference is observed for that trial; however this is thought to occur due to the melange colour of the samples. R-washed sample was passed the quality control tests of the plant and the application saved approximately 11% water.

4 Conclusion

A water saving method is proposed, in which the final bath (neutralisation bath) of the washing processes for cleaning purposes is not drained out but reused in the first step of the next washing process. Following observations are made:

4.1 The experiments show that 10-30% water saving in washing processes can be achieved depending on fabric type. Annual average water consumption for washing processes of the company has been 14,000 tonnes. Thus, nearly 2,800 tonnes/year of water can be saved through the implementation of the presented method.

4.2 The reuse of the last washing water does not have considerable negative effect on the quality of the fabric. Moreover, it should also be indicated that this application does not require an additional storage tank for wastewater collection, hence no investment cost, and it can easily be adapted to the plant through an appropriate process program revision.

4.3 It is not possible to reuse the whole washing water since the fabric carries over a certain amount of water when leaving the dyeing machine. For highly hygroscopic and bulky fabrics, carry-over ratio will be higher. Thus, it is recommended to install a gentle squeezing mangle or just a stripping mangle to the fabric exit to save some of the carry-over water, which will increase the reused water ratio.

4.4 Although it is reported here that the coloration of the washing water due to the reuse of the wastewater does not have a negative effect on colour and fastness of the fabrics, dark shade washing wastewater may be problematic. In this case, a colour level may be determined so that the water below this level can be kept for reuse. Also it should be considered that the multiple reuse of the water may lead to increase in the TDS, COD/BOD etc. of the resultant waste water.

4.5 This study deals with the reuse of wastewater of washing processes applied for cleaning purposes. Thus as a further study, investigation of the reusability of the washing water of textile pretreatment and dyeing processes is recommended for an increased water saving potential.

Acknowledgement

The authors gratefully acknowledge the financial support of İzmir Development Agency (İZKA) through Project No. İEVP-PP-2015-2. Thanks are also due to Mr Adnan Karanfil Nar and Mr Yağmur Güngör for their help in laboratory testing.

References

1 Cuc S & Vidovic M, *Operations and Supply Chain Management*, 4(2/3) (2011) 108.
2 Dawson T, *Color Technol*, 128 (2011) 1.
3 Maia L C, Alves A C & Leão C P, *Sustainable work environment with lean production in textile and garment industry*, paper presented at International Conference on Industrial Engineering and Operations Management, Guimarães, Portugal, 9-11 July 2012.
4 http://eippcb.jrc.ec.europa.eu/reference/BREF/txt_bref_0703.pdf (accessed on 23.02.2017).
5 Chavan R B, *Indian J Fibre Text Res*, 26 (2001) 11.
6 Rott U, *J Environ Sci Heal A*, 38(8) (2003) 1629.
7 Joshi M, Bansal R & Purwar R, *Indian J Fibre Text Res*, 29 (2004) 239.
8 Ergas S J, Therriault B M & Reckhow D A, *J Environ Eng*, 132(3) (2006) 315.
9 Lu X, Liu L, Liu R & Chen J, *Desalination*, 258 (2010) 229.
10 Vajnhandl S & Valh J V, *J Environ Manage*, 141 (2014) 29.
11 Jiang W, Yuan Z, Bi J & Sun L, *J Clean Prod*, 18 (2010) 1696.
12 Alkaya E & Demirer G N, *J Clean Prod*, 65 (2014) 595.
13 Ozturk E, Karaboyacı M, Yetis U, Yigit N O & Kitis M, *J Clean Prod*, 88 (2015) 116.
14 Ozturk E, Koseoglu H, Karaboyacı M, Yigit N O, Yetis U & Kitis M, *J Clean Prod*, 130 (2016) 92.
15 Kiran-Ciliz N, *J Clean Prod*, 11 (2003) 481.
16 Shaikh I A, Suhail E & Munir S, *Technical J UET Taxila*, 20(I) (2015) 18.
17 Osman M S, Saha G C, Islam S M A, Abu Shaid M, Reza M S & Hoque H M A, *Proceedings*, *International Conference on Green Buildings, Civil and Architecture Engineering* (Dubai), 2015, 8.
18 Yang Y & Xu L, *Am Dyest Rep*, 85 (1996) 27.
19 Sonaje N P & Chougule M B, *Int J Adv Res*, 3 (2015) 707.
20 Harane R S & Adivarekar R V, *Int J Chem Tech Res*, 5 (2013) 671.
21 Chattopadhyay S N, Pan N C & Day A, *Bioresource Technol*, 97 (2006) 77.
22 Erdumlu N, Ozipek B, Yilmaz G & Topatan Z, *Autex Res J*, 12 (2012) 23.