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Towards Water-saving Textile Wet Processing. Part 1: Scouring and Dyeing

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THIS work is devoted to try to reduce consumption of water during scouring and dyeing of wool, viscose, and polyester fabrics. This was achieved by scouring wool, viscose, and polyester fabrics by the carbonate salt of sodium, potassium, or ammonium using different material-to-liquor ratios. The scoured fabric was removed from the scouring bath, and the residual liquor was divided into three aliquots. The first aliquot was used directly for dyeing of scoured wool fabric with Acid Blue 193, scoured viscose fabric with Reactive Blue 19, and scoured polyester fabric with Disperse Red 56. The pH of the second aliquot was adjusted to pH 4.5 using dilute hydrochloric acid and then used for dyeing of the scoured fabric with the respective dyes. The third aliquot was adjusted to neutrality by using calcium chloride solution which resulted in precipitation of calcium carbonate; the supernatant of which was taken out of the bath and directly used for the dyeing process. The colour strength of the dyed fabrics was measured and compared to the corresponding conventionally scoured and dyed fabrics. The fastness properties of the dyed fabrics against light, washing, rubbing and perspiration were also assessed. Results of this study revealed that it is possible to use the residual scouring bath of wool, viscose, and polyester fabrics after being rendered acidic or neutral, for their dyeing successfully. Physico-mechanical properties of all scoured fabrics were measured.

Keywords: Water, Saving, Fabric, Scouring, Dyeing.

Introduction

The textile industries consume large quantities of water (200 m^3/ton of product) and generate significant volumes of wastewater (~90 % of consumed water) [1, 2]. Among the textile production processes that leads to water/energy-exhaustive including scouring, washing, dyeing, bleaching, sizing, and finishing [3, 4]. Wet process is the main part of the textile industry due to the long processing time and technical complication [5]. Various factors affecting the water and energy consumption in wet processing including; types and amount of used chemicals as well as the processes conditions such as temperature and time.

Scouring is the first process that is carried out with or without chemicals, at room temperature or at suitable higher temperatures with the addition of suitable wetting agents or alkali. Scouring removes all the waxes, pectins and makes the textile material hydrophilic or water absorbent. Scouring is the process of preparing and washing a batch of raw sheep›s wool to remove impurities such as grease, dirt and suint. Polyester fibres, on the other hand, are relatively clean before wet processing, and a scour with detergent and sodium carbonate is usually sufficient to remove knitting and weaving lubricants if necessary. Scouring of viscose fabric is usually carried out using nonionic detergent [6].

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In scouring processes, water is used to remove natural impurities and to wash out chemicals, with substantial amounts of water required to keep concentrations low and allow diffusion processes to proceed. Many researchers proposed techniques to modify the textile processes to reduce the consumption of water and energy [7 – 9].

Dyeing is the second most water-consuming wet process in textile industry after bleaching. It represents about 16 % of the total consumption of water in wet processing of textiles. Usually 10000 - 30000 gallon of water is consumed for dyeing of one kilogram of textile material. Numerous methods have been developed to conserve water at textile mills. These include good housekeeping, water reuse, use of automatic shut-off or flow control valves, flocculation of clean water of pigment printing, use of single stage of processing, use of low material-to-liquor ratio [10,11], microwave-assisted dyeing, and ultrasonic-assisted dyeing [12].

This work aims at reducing consumption of water during scouring and dyeing of wool, viscose, and polyester fabrics via reuse of the scouring effluent in the dyeing operation. The residual scouring bath is either used directly, or after being treated with calcium chloride solution or dilute hydrochloric acid. Up to our knowledge, the use of scouring bath in dyeing of textiles was not reported in any earlier investigations. The novelty of this work is extended to include the neutralization or acidification of the residual scouring bath before dyeing using calcium chloride solution or hydrochloric acid; respectively.

Experimental

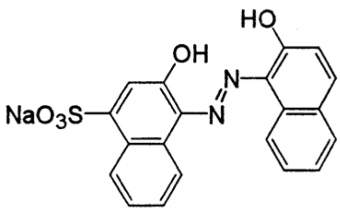
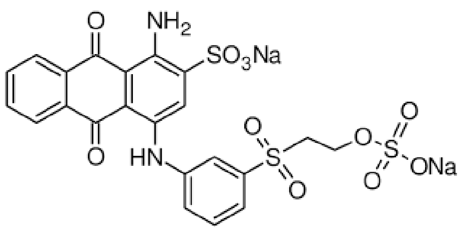
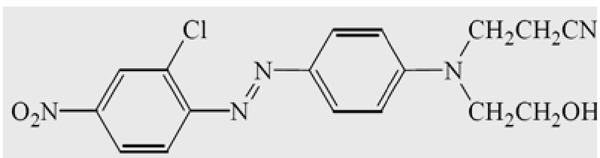
Materials

Pure Australian merino wool woven fabric (210 g ⁄m2), supplied by Misr Company for Spinning and Weaving, El-Mehalla El-Kobra, Egypt, was used in this study. Knitted polyester fabric (160g/m2) was purchased from Kazareen Textile Company, 6th October City, Egypt. Viscose fabric was purchased from Lenzing, Austria. Egyptol PLM was purchased from the Starch and Detergents Company, Alexandria, Egypt. It is a nonionic detergent based on nonyl phenol ethoxylate. All chemical used in this study were of laboratory grade and used without further purification.

Dyes

The acid, reactive and basic dyes used in this study are shown in table 1.

TABLE 1. The chemical structures of the used dyes.

Dye	Chemical structure
C.I. Acid Blue 193	
Reactive Blue 19	
Disperse Red 56	

Methods

Scouring of wool fabric

Using sodium carbonate

Wool fabric was scoured in an aqueous solution of sodium carbonate (2 g/l) in presence of 1 g/l nonionic detergent at 60 °C for 15 min using different liquor ratios (1:15 – 1:50). The scoured sample was then removed from the bath and the residual solution was divided into 3 aliquots. The first one is kept without any additives and its pH was recorded as 9.2. The pH of the second aliquot was adjusted to 7 by adding 0.1 M aqueous calcium chloride solution dropwise, followed by centrifugation to separate the precipitated white calcium carbonate. The pH of the third one was adjusted to 4.5 using 3-4 drops of concentrated hydrochloric acid. The three aliquots were then used for dyeing of wool fabrics.

Using potassium carbonate

In another trial, potassium carbonate solution (2 g/L) was used for scouring of wool fabrics instead of sodium carbonate using the same reaction conditions at a liquor ratio (1:15). The pH of the residual scouring bath was almost similar to that of sodium carbonate. The residual scouring bath was used in dyeing of wool fabric in three different aliquots as those mentioned in case of sodium carbonate bath.

Using ammonium carbonate

In this trial, we used a faint alkaline thermally unstable (above 58 °C) carbonate salt; namely ammonium carbonate for scouring of wool fabrics at 53°C using liquor ratio 1:15 for 15 min. At the end of scouring, the temperature was raised to 60°C for 5 min. At this temperature $(NH_4)_2 CO_3$ decomposes into water, ammonia and carbon dioxide gases. The pH of the residual scouring bath was 7.57.

Scouring of polyester and viscose fabrics

Polyester and viscose fabrics were scoured using the same reagents and conditions used for scouring of wool. The liquor ratio was always 1:15.

Dyeing

The scoured wool, polyester and viscose fabrics were dyed using the said three different baths using their respective dyes; Acid Blue 193 for dyeing of wool fabrics, Disperse Red 56 for dyeing polyester fabrics, and Reactive blue 19 for dyeing viscose fabrics. In all cases, the dye concentration was 1% and the liquor ratio was 1: 40 and the pH of the dyeing bath was 4.5, 7.0, or 9.2.

Dyeing of wool fabrics with Acid Blue 193 was carried out for 90°C for 1 h. The dyeing operation of polyester fabrics with Disperse Red 56 was conducted at 130°C for 30 min. Coloration of viscose fabrics with Reactive Blue 19 was performed at 60 °C for 1 h.

For comparison, the dyeing process of the said scoured fabrics was also carried out in a fresh water bath using the proper dyeing methods.

Analyses

Color measurements

The colorimetric analysis of the dyed fabrics was recorded using a spectrophotometer with pulsed xenon lamps as light source (Ultra Scan Pro, Hunter Lab, USA) 10° observer with D65 illuminant d/2 viewing geometry and measurement area of 2 mm. All measurements were occurred at λmax425 nm wavelength. The corresponding color strength value (K/S) was assessed by applying the Kubelka Munk [13] (Eq. (1)).

$$K/S = \frac{(1-R)^2}{2R} \quad \text{(Eq. 1)}$$

Where R is the decimal fraction of the reflection of the coloredfabric, K is the absorption coefficient and S is the scattering coefficient.

Fastness properties

The fastness properties of the dyed samples were tested according to ISO standard methods. The specific tests were ISO 105-X12 (1987) for color fastness to rubbing; ISO 105-C02 (1989) for color fastness to washing, and ISO 105 E04 (1989) for color fastness to perspiration [14].

Whiteness index

The degree of whiteness of Na_2CO_3-scoured as well as unscoured fabrics was given as W-CIE and performed on a Datacolor colorimeter 3890 (Datacolor Marl).

Mechanical properties

a) *Tensile properties*

The tensile strength and elongation at break of unscoured, Na_2CO_3-scoured/dyed as well as dyed wool and viscose fabrics in scoured bath were measured according to the ASTM standard test method D-1682-1924 on a tensile strength apparatus FMCW 500, Germany. The measurements were carried out at the standard temperature and relative humidity (25°C, 65% RH). The results are the mean of 10 breaks on the warp direction with length and width of 30 and 5 cm at a constant breaking time of 20 s.

b) *Bursting strength*

The polyester fabric bursting strength was tested by using Tinius Olsen material testing machine 500 according to ASTM D3787-2001 by applying 50 kgf load, 95 mm extension range, head speed of 305 mm/min, 90 mm endpoint and 0.1 kgf preload.

Results and Discussion

Aiming to reduce consumption of water during wet processing of some textile fabrics, we tried to decrease the liquor ratio of the scouring bath to its possible minimum extent. Moreover, the scouring bath was used for the subsequent dyeing operation, either directly or after adding certain reagent.

The scouring bath of alkaline pH was either used directly for the dyeing process (bath B1), or after addition of calcium chloride (bath B2) or hydrochloric acid (bath B3) solutions. Addition of calcium chloride solution results in precipitation pf the carbonate anions in the residual scouring solution; and hence the solution turns into nearly neutral medium due to presence of neutral sodium chloride solution in the bath. Sodium chloride is added usually in the dyeing bath as a levelling agent (Glauber salt). Addition of hydrochloric acid was used to decrease the proper pH value for dyeing of wool with acid dyes with formation of sodium chloride as a by-product in the dyeing bath.

Scouring and Dyeing of Wool Fabric

*Scouring of Wool Fabric with Na_2CO_3 Using Dif*ferent Liquor Ratios

Wool fabric was scoured by Na_2CO_3 using different liquor ratios (1:15, 1:25, 1:40, 1:50). The residual scouring bath was used for dyeing of wool fabrics using Acid Blue 193. The results of this investigation were shown in figure 1. This figure implies that as the liquor ratio of the scouring bath decreases, the colour strength of the dyed fabric increases; a result which would be positive sign for the reduction of water consumption in the scouring step. Only dyed fabrics in fresh water (control) deviate from this trend.

At different liquor ratios, samples dyed with fresh water is better than those samples dyed using residual scouring bath at different dyeing pH values. At a liquor ratio 1:15, the K/S values of the dyed fabrics decreases in the order: dyeing in fresh water bath > dyeing in “B2” bath ≈ dyeing in “B3” bath > dyeing in “B1” bath. Utilization of the scouring bath for dyeing of wool will save huge amount of water if applied to industrial scales, even with an acceptable reduction in the colour strength of the dyed fabric.

From the practical point of view, we would recommend dyeing of wool fabrics in the residual scouring bath whose pH value adjusted to 4.5 using HCl rather than the same bath with calcium chloride. The latter bath requires decantation step for the supernatant after precipitation of calcium carbonate.

The similarity of the colour strength of the dyed fabrics in bath “B2” and “B3” is ambiguous and need more investigation for results interpretation. Unlike bath “B3”, bath “B2” is neutral and the amino groups of wool keratin are not protonated to form salt link with the anionic sulphonate group of the dye molecule. This would pave the road towards an interrogative debate; whether the phenolic hydroxyl groups of the dye molecule share in binding the dye molecules with the keratin macromolecules.

Scouring of Wool Fabrics with Different Carbonate Salts

Adopting the optimum liquor ratio of wool scouring, three different carbonate salts; namely Na_2CO_3, K_2CO_3, and $(NH_4)_2CO_3$, were used for scouring of wool, and the residual scouring bath was utilized in dyeing of wool in the same way declared in section 3.1.1.

Ammonium carbonate has the advantage of being faint alkaline which would prevent the conversion of cystine residues along keratin macromolecules into lanthionine residues, which is usually taken place during scouring of wool with sodium carbonate. Conversion of cystine into lanthionine is an irreversible reaction and results in some brittleness in the fabric. Moreover, ammonium carbonate decomposes after 58°C to water, carbon dioxide and ammonia gases.

Results of this study, shown in figures 2 and 3, indicate that the K/S values of the dyed samples in the residual K_2CO_3 or $(NH_4)_2CO_3$-scouring bath are in the same order as that in case of using Na_2CO_3-scouring bath. Upon comparing the colour strength of the wool fabrics dyed in the residual scouring bath relative to the respective scoured samples dyed using a fresh water bath; we find that sodium carbonate is the best scouring agent, and ammonium carbonate is better than potassium carbonate, regarding the K/S value of the dyed samples.

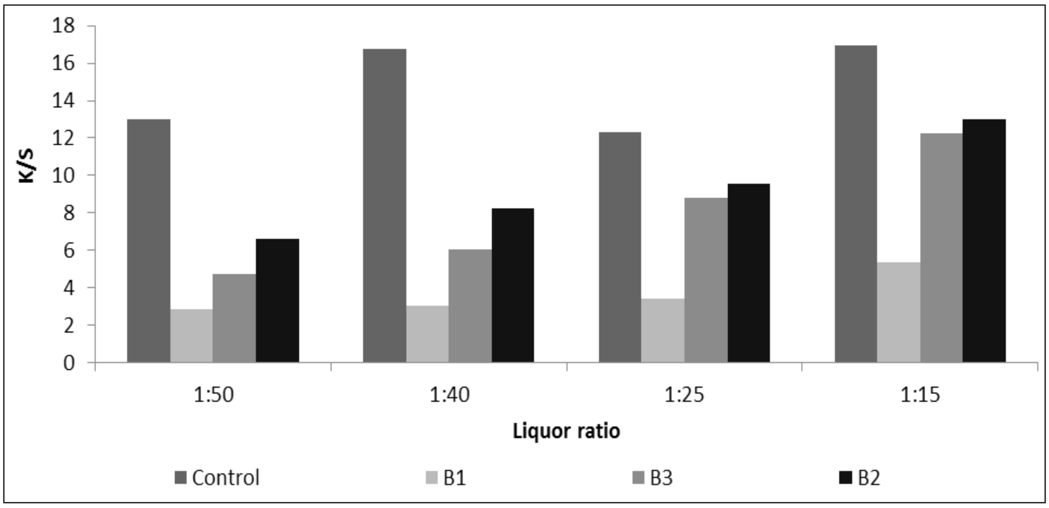


Fig. 1. Colour strength of dyed wool fabrics: dyeing was carried out using fresh water, or in "B1", "B2", or "B3" baths. (Dyeing conditions: 1% shade, at 90 °C for 60 min, liquor ratio 1:40).

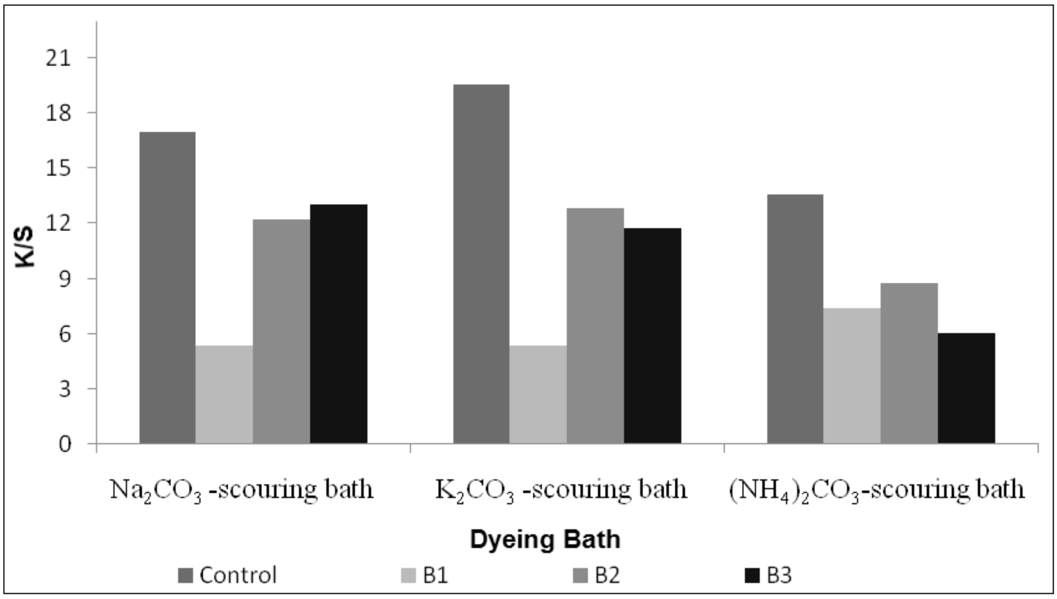


Fig. 2. Color strength of dyed wool fabrics using different scouring baths: dyeing was carried out using fresh water (control), or in "B1", "B2", or "B3" baths. (Dyeing conditions: 1% shade, at 90 °C for 60 min, liquor ratio 1:40).

Fastness Properties of scoured/Dyed Wool Fabrics

Table 2 summarizes the fastness properties of the scoured/dyed wool using different scoured carbonate salts.

Results of Table 2 show that, there is slight change in fastness properties of the scoured/dyed wool using different scouring reagents and baths and adjusted by HCl as compared to the scoured/dyed sample into two consecutive fresh baths.

Scouring/dyeing of polyester fabric

Polyester fabric was scoured in a bath containing sodium, potassium, or ammonium carbonate, followed by dyeing using Disperse Red 56 at different pH values. The colour strength of the scoured/dyed polyester was presented in figure 3.

TABLE 2. Fastness Properties to light, rubbing, washing, and perspiration of scoured/dyed wool.

Sample	Light Fastness	Rubbing Fastness		Washing Fastness			Perspiration					
							Acid			Alkaline		
		Dry	Wet	St*	St**	Alt	St*	St**	Alt	St*	St**	Alt
Dyed using Na_2CO_3 scoured bath	6	3-4	2-3	4	4	4	4	4	4	4	4	4
Dyed using Na_2CO_3 scoured bath adjusted by HCl	5	3-4	2-3	4	4	4	4	4	4	4	4	4
Dyed using K_2CO_3 scoured bath	5-6	2-3	2	4	3-4	4	4	4	4	4	4	4
Dyed using K_2CO_3 scoured bath adjusted by HCl	5	3-4	3	4	4	4	4	4	4	4	4	4
Dyed using $(NH_4)_2CO_3$ scoured bath	5-6	2-3	2-3	4	3-4	4	4	4	4	4	4	4
Dyed using $(NH_4)_2CO_3$ scoured bath adjusted by HCl	5	3-4	2-3	4	3-4	4	4	4	4	4	4	4

St*: staining on cotton, St**: staining on wool, Alt: changing in color

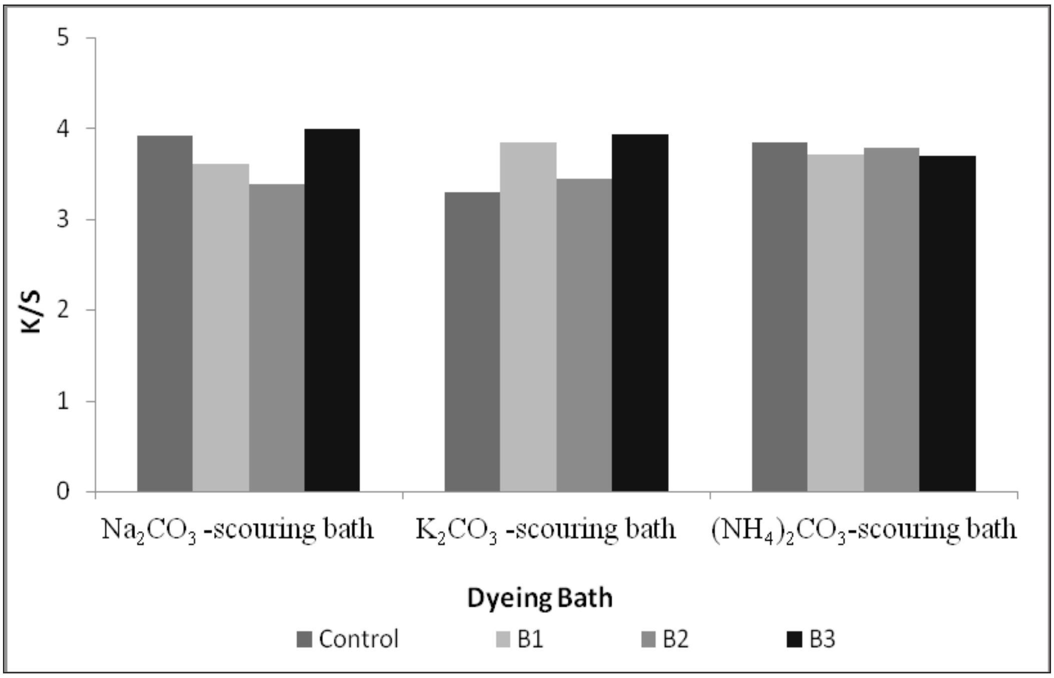


Fig. 3. Color strength of dyed wool fabrics using different scouring baths: dyeing was carried out using fresh water (control), or in "B1", "B2", or "B3" baths. (Dyeing conditions: 1% shade, at 130 °C for 40 min, liquor ratio 1:40).

It is obvious from these figures that the colour strength of polyester scoured and dyed sample in two different baths is close to that of the samples dyed in the residual scouring whose pH that was adjusted by HCl. Moreover, the colour strength of the dyed polyester in Na_2CO_3 residual scouring bath adjusted by HCl is higher than scoured/dyed sample into two consecutive different baths.

Fastness Properties of Dyed polyester Fabric

Table 3 shows the fastness properties of the scoured/dyed polyester fabric using different scoured carbonate salts.

Date of this table clarify that the fastness properties of the scoured/dyed polyester using different scoured carbonate salts baths and whose pH value adjusted by HCl are similar that of the scoured/dyed sample into two consecutive different baths.

Scouring/dyeing of Viscose fabric

Viscose fabric was scoured by the three different carbonate salts then dyed by Reactive Blue 19 using these baths at three different pH values. The colour strength of the scoured/dyed polyester fabric is presented in figures 4.

This figure elucidates that the color strength of viscose dyed in $(NH4)_2CO_3$ scoured bath is small comparing with that of the scoured/dyed sample into two consecutive different baths. In the other hand, the colour strength of the dyed viscose in Na_2CO_3 scoured bath whose pH was adjusted by HCl decreased by about 30% comparing with that of the scoured/dyed sample into two consecutive different baths.

Fastness Properties of scoured/Dyed Viscose Fabrics

Table 4 show fastness properties of the scoured and dyed wool using different scouring carbonate salts.

Data of table 4 indicated that there are no alterations in the fastness properties of the scoured and dyed viscose using different scoured carbonate baths after being adjusted by HCl as compared to the scoured/dyed sample into two consecutive different baths.

Whiteness index

The effect of different scouring reagents on the degree of whiteness of wool, polyester, and viscose was measured. Results of this investigation, summarized in Table 5, elucidate that scouring of wool using sodium or potassium carbonate solution causes remarkable decrease in the degree of whiteness of wool fabrics. Sodium carbonate was reported as one of the reagents that cause yellowing of wool fabrics together with an irreversible transformation of cystine residues along keratin macromolecules into lanthionine [15]. Ammonium carbonate, on the other hand, has no appreciable effect on the degree of whiteness of wool, presumably due to its lower alkalinity relative to sodium and potassium carbonates.

TABLE 3. Fastness properties to light, rubbing, washing, and perspiration of scoured/dyed polyester.

Sample	Light Fastness	Rubbing Fastness		Washing Fastness			Perspiration					
							Acid			Alkaline		
		Dry	Wet	St*	St**	Alt	St*	St**	Alt	St*	St**	Alt
Dyed using Na_2CO_3 scoured bath	6	4	4	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Dyed using Na_2CO_3 scoured bath adjusted by HCl	6	4	4	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Dyed using K_2CO_3 scoured bath	6	3-4	3-4	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Dyed using K_2CO_3 scoured bath adjusted by HCl	6	4-5	4	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Dyed using $(NH_4)_2CO_3$ scoured bath	6	4	4	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Dyed using $(NH_4)_2CO_3$ scoured bath adjusted by HCl	6	4-5	4	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5

St*: staining on cotton St**: staining on wool Alt: changing in color

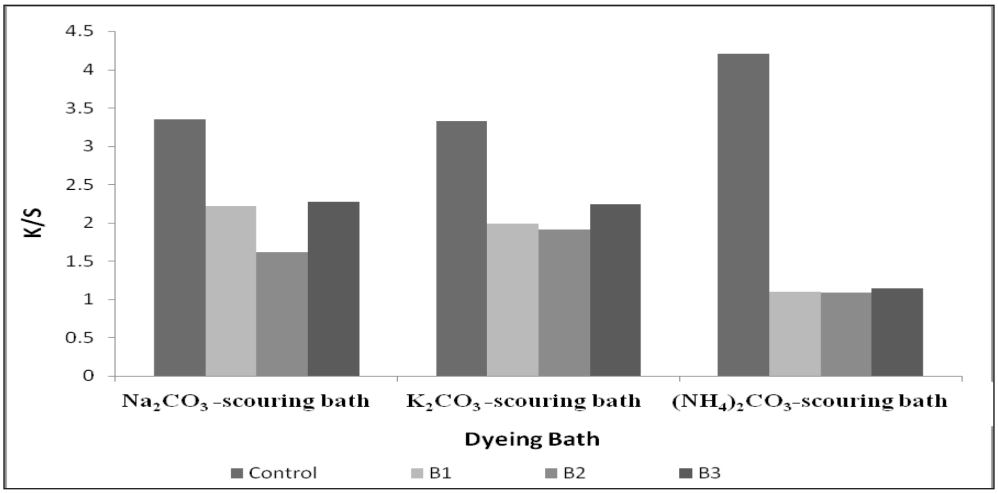


Fig. 4. Color strength of dyed viscose fabrics using different scouring baths: dyeing was carried out using fresh water (control), or in "B1", "B2", or "B3" baths. (Dyeing conditions: 1% shade, at 60 °C for 60 min, liquor ratio 1:40).

TABLE 4. Fastness Properties to light, rubbing, washing, and perspiration of scoured/dyed Viscose.

Sample	Light Fastness	Rubbing Fastness		Washing Fastness			Perspiration					
							Acid			Alkaline		
		Dry	Wet	St*	St**	Alt	St*	St**	Alt	St*	St**	Alt
Dyed using Na_2CO_3 scoured bath	6	3-4	3-4	4	3-4	4	4	4	4	4	4	4
Dyed using Na_2CO_3 scoured bath adjusted by HCl	5-6	4	3-4	4	3-4	4	4	4	4	4	4	4
Dyed using K_2CO_3 scoured bath	5	3-4	3-4	4	3-4	4	4	4	4	4	4	4
Dyed using K_2CO_3 scoured bath adjusted by HCl	5-6	3-4	3	4	3-4	4	4	4	4	4	4	4
Dyed using $(NH_4)_2CO_3$ scoured bath	5-6	3-4	3	4	3-4	4	4	4	4	4	4	4
Dyed using $(NH_4)_2CO_3$ scoured bath adjusted by HCl	5	3-4	3	4	3	4	4	4	4	4	4	4

St*: staining on cotton St**: staining on wool Alt: changing in color

TABLE 5. Whiteness index of scoured wool, polyester, and viscose fabrics .

Sample	Whiteness index (YI)
Untreated wool fabrics	16.6
Wool fabric scoured with Na_2CO_3	15.3
Wool fabric scoured with K_2CO_3	15.2
Wool fabric scoured with $(NH_4)_2CO_3$	16.5
Untreated polyester fabric	115.3
Polyester fabric scoured with Na_2CO_3	115.0
Polyester fabric scoured with K_2CO_3	115.2
Polyester fabric scoured with $(NH_4)_2CO_3$	115.5
Untreated viscose fabrics	53.0
Viscose fabric scoured with Na_2CO_3	60.5
Viscose fabric scoured with K_2CO_3	60.1
Viscose fabric scoured with $(NH_4)_2CO_3$	60.1

The whiteness index of polyester fabrics were not affected after being scoured using the aforementioned carbonate salts. In Contrary, the whiteness index of viscose fabrics was improved significantly upon scouring using the said aqueous carbonate solutions.

Mechanical properties

The tensile strength and elongation at break of scoured/dyed as well as untreated wool and viscose fabrics were measured. The burst strength of the analogous knitted polyester fabrics was also assessed.

Data in Table 6 illustrates that there is slight decrease in the tensile strength of the scoured and dyed fabrics compared to the corresponding untreated fabrics. On the other hand, the elongation at break of the treated and dyed fabrics was remarkably enhanced compared to their untreated analogous fabrics.

The burst strength was used to assess the effect of scouring followed by dyeing within the residual scouring bath, on the strength of the treated polyester fabrics. Table 7 reveals that there is no appreciable effect on the burst strength of polyester fabrics when dyed in the residual scouring bath whose pH value was adjusted to 4.5 using HCl.

TABLE 6. Tensile strength and elongation at break of untreated as well as treated wool and viscose fabrics (scouring by 1 g/L Na_2CO_3; and dyeing in s residual scouring bath at pH 4.5 adjusted by HCl).

Sample	Tensile strength (kgf)	Elongation at break (%)
Untreated wool fabric	41	46
Scoured and dyed wool fabric	43	55
Dyed wool fabric in the scouring bath	45	55
Untreated viscose fabric	49	26
Scoured and dyed viscose fabric	51	37
Dyed viscose fabric in the scouring bath	53	35

TABLE 7. Bursting strength of untreated as well as treated polyester fabrics (scouring by 1 g/L Na_2CO_3; and dyeing in s residual scouring bath at pH 4.5 adjusted by HCl).

Sample	Bursting strength (Kg/cm^2)
Untreated polyester fabric	10.6
Scoured and dyed polyester fabric	10.8
Dyed polyester fabric in the scouring bath	10.6

Conclusion

Consumption of water in wet processing of textile fabrics is possible by utilizing the same bath for two processes. This was achieved by utilizing the residual scouring bath of wool, polyester, or viscose fabrics in their dyeing with the respective class of dyes. The scouring bath was either used directly or after being treated with hydrochloric acid to adjust its pH to the proper value for dyeing. Results of this study revealed that it is possible to use the scouring bath of wool, viscose, and polyester fabrics after being rendered acidic, for their dyeing successfully without appreciable effect on their colour strength and fastness properties. Furthermore, there is no remarkable change on the physic-mechanical properties of all scoured/dyed fabrics compared to the scoured and dyed fabrics into two consecutive fresh baths.

Furthermore, consumption of water can be reduced significantly by using lower liquor ratios during scouring (below to 1:15) and dyeing (below to 1:40) with remarkable improvement in the colour strength of the dyed fabrics.

Based on the results obtained, we recommend sodium carbonate as a scouring agent for the said fabrics rather than potassium and ammonium carbonate.

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نحو عمليات نسجية رطبة موفرة للماء: الجزء الاول: الغسيل والصباغة

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يهدف هذا العمل إلى تقليل استهلاك المياه أثناء غسيل وصباغة أقمشة الصوف، الفسكوز، والبولى إستر. تم إنجاز هذا العمل عن طريق غسيل قماش الصوف، الفسكوز والبولى إستر باستخدام أملاح كربونات الصوديوم، البوتاسيوم أو الامونيوم بنسب مواد إلى محلول (liquor ratio) مختلفة. ثم تم إزالة القماش من حمام الغسيل وتم تقسيمه إلى ثلاث حمامات. الأول تم إستخدامه مباشرة فى صباغة الصوف المغسول بالصبغة الحامضية Acid Blue 193، والفسكوز المغسول بالصبغة النشطة Reactive Blue 19 والبولى إستر المغسول بالصبغة المشتتة Disperse Red 56. أما بالنسبة للحمام الثانى فتم تعديل رقم الأس الهيدروجينى له إلى ٤,٥ بإستخدام حمض الهيدروكلوريك المخفف ثم استخدامه فى صباغة الاقمشة المغسولة بالصبغات المناسبة. كما تم تعديل رقم الأس الهيدروجينى للحمام الثالث إلى ٧,٠ وذلك باستخدام محلول كلوريدالكالسيوم الذي أدى إلى ترسيب كربونات الكالسيوم والتى تم فصلها من الحمام واستخدام الحمام الناتج مباشرة فى عملية الصباغة.

تم قياس شدة اللون للاقمشة المصبوغة ومقارنتها بالأقمشة المصبوغة بالطريقة التقليدية وهي الغسيل والصباغة فى حمامين مختلفين. كما تم تقييم خصائص ثبات الأقمشة المصبوغة للضوء والغسيل والاحتكاك والتعرق. حيث أوضحت نتائج هذه الدراسة أنه من الممكن استخدام حمام الغسيل المتبقى للصوف والفسكوز والبولي إستر بعد أن تصبح حمضية أو متعادلة فى عملية الصباغة بنجاح كما تم قياس بعض الخواص الفيزيقوميكانيكية لجميع الأقمشة المغسولة والمصبوغة.