ELSEVIER

Dyes and Pigments, Vol. 29, No. 2, pp. 139–153, 1995

0143-7208/95 $9.50 + 0.00

0143-7208(95)00033-X

A Study of the Wash-off and Aftertreatment of Dichlorotriazinyl Reactive Dyes on Cotton

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(Received 10 March 1995; accepted 5 April 1995)

ABSTRACT

Five commercial dichlorotriazinyl reactive dyes, applied at 1, 2 and 4% omf to cotton fabric, were washed-off using four water-based methods and one detergent-based method; the washed-off dyeings were then subjected to the ISOC06/C2 wash fastness test. None of the four water-based wash-off methods used resulted in the dyeings achieving a level of fastness that was as high as that achieved using the detergent-based wash-off method. The fastness to washing of the dyeings which had been washed-off using the four water-based methods was improved using an aftertreatment involving two proprietary cationic fixing agents. The extent of improvement in wash fastness imparted by each fixing agent increased with increasing severity (temperature) of the wash-off method. In the case of dyeings that had been washed-off using water at 80°C and 98°C, aftertreatment with the two cationic fixing agents resulted in wash fastness ratings that were either identical to, or only one-half point lower than, comparable depth dyeings which had been washed-off using detergent. The colour strength of the washed dyeings that had been washed-off using water and aftertreated with the two cationic fixing agents was greater than that of comparable depth, washed dyeings that had been washed-off using detergent.

INTRODUCTION

Several classes of dye can be used to dye cellulosic fibres, namely vat, direct, reactive, sulphur and azoic colorants, the different classes varying in terms of factors such as their cost, ease of application, fastness properties, etc.

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Characteristically, reactive dyes furnish a wide gamut of shades of good light fastness and excellent wash fastness on cellulosic fibres. However, although reactive dyes are widely used for the exhaustion dyeing of cotton and other cellulosic fibres, the dyes suffer the disadvantage that dye–fibre reaction is not 100% efficient. This can be attributed to incomplete exhaustion of the dye, to incomplete reaction of the adsorbed dye with the fibre and, more importantly, because the dyes can react not only with the fibre nucleophile (cellulosate anion) but also with nucleophiles (commonly hydroxyl ions) present in the dyebath, to dye hydrolysis. As a consequence, in order to achieve optimum fastness to wet treatments, the resultant dyeings need to be thoroughly washed-off to remove both unreacted and hydrolysed dye. The wash-off procedures employed for reactive dyeings on cellulosic fibres vary according to different maker's recommendations; however, such procedures, which often involve the use of detergents and/or other additives at high temperature (commonly 80–98°C), are time-consuming and wasteful of water and chemicals.

Whilst direct dyes generally exhibit high exhaustion on cellulosic fibres and provide a wide range of bright shades of good light fastness, the dyes display only poor to moderate wash fastness on the substrate; however, the fastness of direct dyes on cellulosic fibres to washing and other wet treatments can be markedly improved by aftertreating the dyeings with a cationic fixing agent.

Such cationic fixing agents can also be used as an aftertreatment to improve the wet fastness of reactive dyes on cellulosic fibres,[1] especially when the dyed material has not been efficiently washed off after dyeing.[1,2]

The purposes of this work were to determine the effectiveness of several wash-off procedures in removing unfixed reactive/hydrolysed dye, and also to assess the effectiveness of an aftertreatment with two proprietary cationic fixing agents on the wash fastness of commercial dichlorotriazinyl reactive dyes on cotton fabric.

EXPERIMENTAL

Materials

Fabric

Scoured and bleached, fluorescent brightener-free woven cotton (150·1 g m^{-2}) was used.

Dyes and auxiliaries

Commercial samples of Procion Red MX-5B (CI Reactive Red 2), Procion

Red MX-8B (CI Reactive Red 11), Procion Blue MX-G (CI Reactive Blue 163), Procion Blue MX-2G (CI Reactive Blue 109) and Procion Yellow MX-4G (CI Reactive Yellow 22), each kindly supplied by Zeneca Specialities, were employed.

Cationic fixing agents
Commercial samples of Matexil FC-ER and Matexil FC-PN were generously supplied by ICI Surfactants.

Other reagents
A commercial sample of Sandozin NIE was kindly supplied by Sandoz (UK).

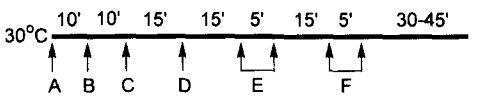
All other reagents were of AnalaR grade.

Procedures

Dyeing
All dyeings (1, 2 and 4% omf) were carried out using fabric which had been wetted out in cold tap water, in 200 cm^3 capacity glass pots housed in a Zeltex Vistacolor laboratory-scale dyeing machine, using a 20 : 1 liquor to goods ratio. The dyeing method used[3] is shown in Fig. 1.

Wash-off of dyeings
At the end of dyeing, the dyed fabric was subjected to one of the following treatments:

(a) rinsing (twice) in cold tap water for 10 min followed by wash-off using an aqueous solution containing 0·5 g l^{-1} Sandozin NIE at 98°C for 30 min, rinsing in tap water at 50°C for 10 min and final rinsing in cold tap water;



pH adjusted to below 7 prior to adding dye

A	Dye	1, 2 or 4% omf
B	NaCl	2.5 g dm^{-3}
C	NaCl	7.5 g dm^{-3}
D	NaCl	25 g dm^{-3} (35 g dm^{-3})
E	Na_2CO_3	0.5 g dm^{-3}
F	Na_2CO_3	3.5 g dm^{-3} (7.5 g dm^{-3})

Fig. 1. Dyeing method (numbers in parentheses refer to 4% omf dyeing).

(b) rinsing in tap water at 20°C for 15 min;
(c) rinsing in tap water at 60°C for 15 min;
(d) rinsing in tap water at 80°C for 15 min;
(e) rinsing in tap water at 98°C for 15 min.

Method (a) was based on that recommended by ICI.[3]

Wash fastness determination

The washed-off, dyed samples were subjected to the ISOC06/C2[4] wash test. In the cases of wash-off methods (b) to (e) above, the dyeings were also aftertreated with each of the two cationic fixing agents and the resultant dyeings then subjected to the ISOC06/C2[4] wash test. In all cases, the washed, dyed sample was finally rinsed thoroughly in tap water before being allowed to dry in the open air.

Aftertreatment of washed-off dyeings

Aftertreatment with either of the two cationic fixing agents, using an aqueous (distilled water) solution comprising (0·5 × % omf dye) omf fixing agent, was carried out using the same apparatus as used for dyeing, for 30 min at 40°C using a 20 : 1 liquor to goods ratio. The aftertreated, dyed sample was finally rinsed thoroughly in tap water before being allowed to dry in the open air.

Colour measurement

The reflectance values of the dry dyeings were measured, both before and after wash fastness testing, employing a Macbeth MS2020 spectrophotometer interfaced to a Digital PC under illuminant D_{65}, using a 10° standard observer with specular component excluded and UV component included; the corresponding K/S value at the λ_{max} of the dyeing was calculated both before (K_1/S_1) and after (K_2/S_2) wash fastness testing.

RESULTS AND DISCUSSION

Dyeings which were not aftertreated

Table 1 shows the wash fastness results obtained for 1, 2 and 4% omf dyeings, for each of the five dyes used, which had been washed-off using method (a), namely that involving several rinses and hot detergent. For each depth of shade of each dye used, it is evident that the wash fastness

TABLE 1
Wash Fastness Results for Dyeings Washed-off using Detergent and Receiving no Aftertreatment

Dye	*% omf*	*Shade change*	*Staining of adjacent cotton*	*Staining of adjacent viscose*	K_1/S_1	K_2/S_2
CI Reactive	1	4/5	4/5	4/5	3·31	3·01
Blue 163	2	4	4/5	4/5	5·47	5·10
	4	4	4	4/5	10·26	8·72
CI Reactive	1	5	4/5	4/5	2·57	2·39
Blue 109	2	4	4/5	4/5	4·66	4·28
	4	4	4/5	4/5	8·78	7·63
CI Reactive	1	5	4	4/5	4·15	4·05
Red 2	2	4	4	4/5	8·44	7·14
	4	4	4	4/5	14·00	11·04
CI Reactive	1	4/5	4/5	4/5	5·54	5·15
Red 11	2	4/5	4/5	4/5	11·04	10·32
	4	4	4	4/5	17·63	15·92
CI Reactive	1	5	5	4/5	1·50	1·40
Yellow 22	2	4/5	4/5	4/5	2·18	2·16
	4	4/5	4/5	4/5	3·82	3·54

ratings were higher for the 1% omf dyeings than for the two other depths of shade used; this is to be expected. Also, Table 1 shows that the fastness ratings of the 2% and 4% omf dyeings, for each dye used, were identical. This latter finding was not expected as, in general, wash fastness decreases with increasing depth of shade. The results presented in Table 1 also show that none of the dyeings achieved a rating of 5 for each of the three assessed parameters in the ISOC06/C2 wash test, namely change in shade, staining of adjacent cotton and staining of adjacent viscose. This implies that for the three depths of shade and five days used, a more severe wash-off method would need to be employed in order to achieve a wash fastness rating of excellent (i.e. a rating of 5 for each of the three assessed parameters in the ISOC06/C2 wash test).

The fastness results secured for dyeings which had been washed-off using water at 20, 60, 80 and 98°C for 15 min are displayed in Tables 2–5. It is evident that for each dye and at each depth of shade used, the fastness ratings increase with increasing severity (temperature) of the wash-off method employed. As, theoretically, only unfixed reactive dye will be removed from the dyed fibre during wash-off, it follows that as the severity of the wash-off method increases, the extent of removal of unfixed dye should increase and, therefore, that the wash fastness ratings should have increased with increasing severity of the wash-off procedure,

TABLE 2
Wash Fastness Results for Dyeings Washed-off using Water at 20°C and Receiving no Aftertreatment

Dye	*% omf*	*Shade change*	*Staining of adjacent cotton*	*Staining of adjacent viscose*	K_1/S_1	K_2/S_2	$\Delta K/S$
CI Reactive	1	3/4	4	4/5	4·89	4·21	+28·5
Blue 163	2	3/4	3/4	4/5	8·03	6·51	+21·8
	4	3/4	3	4	13·30	11·22	+22·3
CI Reactive	1	3/4	4/5	4/5	3·00	2·78	+14·0
Blue 109	2	3/4	4/5	4/5	5·69	5·41	+20·9
	4	4	4	4/5	10·33	9·62	+20·7
CI Reactive	1	3	3	3/4	4·76	3·92	−3·3
Red 2	2	3/4	3	3/4	8·97	7·10	−0·6
	4	3	3	4	15·11	11·00	−0·4
CI Reactive	1	3/4	3/4	4	6·45	5·71	+9·8
Red 11	2	3	3	4	12·19	10·33	+0·1
	4	4	4	4/5	19·30	17·18	+7·3
CI Reactive	1	4	5	4/5	1·68	1·53	+8·5
Yellow 22	2	3/4	5	4/5	2·44	2·23	+3·1
	4	3/4	4/5	4/5	4·41	3·84	+7·8

TABLE 3
Wash Fastness Results for Dyeings Washed-off using Water at 60°C and Receiving no Aftertreatment

Dye	*% omf*	*Shade change*	*Staining of adjacent cotton*	*Staining of adjacent viscose*	K_1/S_1	K_2/S_2	$\Delta K/S$
CI Reactive	1	4	4	4/5	4·37	3·70	+18·9
Blue 163	2	3/4	4	4/5	7·62	6·37	+19·9
	4	4	4	4/5	11·61	10·52	+17·1
CI Reactive	1	4/5	4/5	4/5	2·99	2·91	+17·9
Blue 109	2	4/5	4/5	4/5	5·62	5·19	+17·5
	4	4	4/5	4	10·44	9·13	+16·4
CI Reactive	1	3/4	3/4	4/5	4·59	3·95	−2·5
Red 2	2	3/4	3/4	4/5	8·52	7·01	−1·8
	4	3/4	3	4	14·78	10·79	−2·3
CI Reactive	1	3/4	4	4/5	6·53	6·41	+19·6
Red 11	2	3	3/4	4	12·12	11·46	+9·9
	4	4	4	4/5	19·11	17·58	+9·4
CI Reactive	1	4	5	4/5	1·52	1·41	+0·7
Yellow 22	2	3/4	5	4/5	2·36	2·22	+2·7
	4	3/4	4/5	4/5	4·06	3·75	+5·6

TABLE 4
Wash Fastness Results for Dyeings Washed-off using Water at 80°C and Receiving no Aftertreatment

Dye	*% omf*	*Shade change*	*Staining of adjacent cotton*	*Staining of adjacent viscose*	K_1/S_1	K_2/S_2	$\Delta K/S$
CI Reactive Blue 163	1	3/4	4	4/5	4·50	3·71	+18·9
	2	4	4	4/5	7·20	6·72	+24·1
	4	3/4	4	4/5	12·38	10·38	+16·0
CI Reactive Blue 109	1	4	4/5	4/5	3·10	2·98	+19·8
	2	4	4/5	4/5	5·67	5·07	+15·6
	4	4/5	4/5	4/5	9·90	9·68	+21·2
CI Reactive Red 2	1	4	4	4/5	4·57	3·83	−5·7
	2	4	4	4/5	8·67	7·23	+1·2
	4	3/4	3/4	4/5	14·81	11·28	+2·1
CI Reactive Red 11	1	3/4	4	4/5	6·42	5·92	+13·0
	2	3	3/4	4/5	13·17	11·01	+6·3
	4	4	4/5	4/5	19·32	17·62	+9·6
CI Reactive Yellow 22	1	4	5	4/5	1·47	1·41	+0·7
	2	3/4	5	4/5	2·19	2·17	+0·5
	4	3/4	5	4/5	4·19	3·82	+7·3

TABLE 5
Wash Fastness Results for Dyeings Washed-off using Water at 98°C and Receiving no Aftertreatment

Dye	*% omf*	*Shade change*	*Staining of adjacent cotton*	*Staining of adjacent viscose*	K_1/S_1	K_2/S_2	$\Delta K/S$
CI Reactive Blue 163	1	4	4/5	4/5	4·34	3·67	+18·0
	2	4	4	4/5	7·28	7·02	+27·3
	4	3/4	4	4/5	12·20	10·88	+19·8
CI Reactive Blue 109	1	4/5	4/5	4/5	3·04	2·82	+15·2
	2	4/5	4/5	4/5	5·31	4·80	+10·8
	4	4	4/5	4/5	10·01	8·83	+13·6
CI Reactive Red 2	1	4	4	4/5	4·51	3·95	−2·5
	2	3/4	4	4/5	8·67	7·03	−1·6
	4	3/4	3/4	4/5	14·90	11·16	+0·2
CI Reactive Red 11	1	3/4	4	4/5	6·35	5·70	+9·6
	2	3/4	4	4	11·36	10·55	+2·2
	4	3/4	3/4	4/5	18·83	17·33	+8·1
CI Reactive Yellow 22	1	4	5	4/5	1·45	1·37	−2·2
	2	4	5	4/5	2·14	2·12	−1·9
	4	3/4	4/5	4/5	4·27	3·87	+8·5

as indeed was observed. Tables 2–5 also reveal that for each of the four wash-off methods used, wash fastness generally decreased with increasing depth of shade applied, which is to be expected. The results displayed in Tables 2–5 clearly show that none of the four water-based wash-off methods used resulted in the dyeings achieving a level of fastness that was as high as that achieved using the detergent-based wash-off method (Table 1). Thus, none of the water-based wash-off methods was as effective as the detergent-based method in removing unfixed dye from the dyed fabric.

However, the fastness results presented in Table 1, and in Tables 2–5, are not comparable in that although the same amount of each dye (i.e. 1, 2 and 4% omf) had initially been used, the colour strength of the dyeings after wash-off differed owing to the varying severity of the five wash-off methods employed. This is illustrated, in Tables 1–5, by the K/S values of the various dyeings before washing (K_1/S_1). A comparison of the K/S values for the dyeings that had been washed-off using water only (Tables 2–5) with those for dyeings that had been washed-off using detergent (Table 1) reveals that the colour strength of the water washed-off samples was higher than that of comparable depth dyeings which had been washed-off using detergent. Furthermore, Tables 2–5 show that, in general, the colour strength of the dyeings which had been washed-off with water decreased with increasing severity (temperature) of the wash-off method employed. These findings are to be expected since, as mentioned above, the extent of removal of unfixed dye should increase with increasing severity of the wash-off and, therefore, the colour strength of the water washed-off dyeings should have decreased with increasing severity of the wash-off procedure, as indeed was observed.

As previously mentioned, wash fastness generally decreases with increasing depth of shade. It therefore follows that in the case of the dyeings which had been washed-off using water (Tables 2–5), as the depth of shade of the dyeings before the wash test was carried out (K_1/S_1) decreased with increasing temperature of wash-off, the fastness ratings achieved should also have increased with increasing temperature of wash-off, as was indeed found. A corollary of this situation is that even though the wash fastness ratings of the dyeings which had received only a water wash-off were lower than those of comparable depth dyeings which had been wshed-off using detergent, the final depth of shade secured *after* the wash test (K_2/S_2) was, with only relatively few exceptions, greater for those dyeings which had been wsahed-off using detergent. This is shown firstly by comparing, in Tables 1–5, the K/S values of the various dyeings after washing (K_2/S_2), and secondly by the $\Delta K/S$ values shown in Tables 2–5. This parameter, $\Delta K/S$, was calculated using eqn (1), where K_a/S_a and

K_b/S_b represent the colour strengths, after washing testing, of a dyed sample which had been washed-off using water and a comparable dyeing that had been washed-off using detergent, respectively.

$$\Delta K/S = \frac{(K_a/S_a - K_b/S_b)}{K_b/S_b} \times 100 \quad (1)$$

From eqn (1), a positive value of $\Delta K/S$ indicates that the colour strength of the washed dyeing which had been washed-off using water was greater than that of the comparable depth, washed dyeing that had been washed-off using detergent; a negative $\Delta K/S$ value shows that the dyeing which had been washed-off using detergent was of greater colour strength than that of a comparable depth, washed dyeing that had been washed-off using water. The $\Delta K/S$ values in Tables 2–5 reveal that with a few exceptions, notably some of the dyeings achieved using CI Reactive Red 2, the colour strength of the washed dyeings that had been washed-off using water was greater than that of comparable depth, washed dyeings that had been washed-off using detergent. Thus, whilst the wash fastness ratings achieved for the dyeings that had been washed-off using water (Tables 2–5) were lower than their counterparts which had been washed-off using detergent (Table 1), the final colour strength (depth of shade) of the former dyeings was higher.

Dyeings aftertreated with cationic fixing agents

An aftertreatment with a cationic fixing agent is widely used as a means of improving the wash fastness of direct dyes on cellulosic fibres. Typically, such fixing agents are quaternary ammonium compounds[5,6] and usually of high M_r; the two particular cationic fixing agents used in this work, namely Matexil FC-PN and Matexil FC-ER, are described, respectively, as[3] '*a nitrogenous condensation product*' and '*an aqueous solution of a low M_r resin*'. As direct dyes are anionic in nature, wash fastness improvement is achieved, typically, by the formation of a dye–cationic agent complex[5,6] of low aqueous solubility;[5,6] in the case of the aftertreatment of reactive dyes on cellulosic fibres with cationic fixing agents, improved wet fastness is achieved in a similar manner, namely by means of complex formation involving the anionic reactive dye.[1]

The wash fastness results obtained for 1, 2 and 4% omf dyeings, for each of the five dyes used, which had been washed-off using methods (b)–(e), namely using water at 20, 60, 80 and 98°C for 15 min, and then aftertreated using Matexil FC-ER and also Matexil FC-PN, are shown in Tables 6–9 and 10–13, respectively. A comparison of the wash fastness ratings displayed in Tables 6–9 and in Tables 10–13 with those shown in

TABLE 6
Wash Fastness Results for Dyeings Washed-off using Water at 20°C and Aftertreated using Matexil FC-ER

Dye	*% omf*	*Shade change*	*Staining of adjacent cotton*	*Staining of adjacent viscose*	K_1/S_1	K_2/S_2	$\Delta K/S$
CI Reactive Blue 163	1	3/4	4	4/5	4·09	3·62	+16·8
	2	3/4	3/4	4/5	7·54	6·77	+24·7
	4	3	3/4	4/5	11·90	10·80	+19·2
CI Reactive Blue 109	1	4	4/5	4/5	2·96	2·78	+14·0
	2	4	4	4/5	4·83	4·73	+9·5
	4	4	4	4/5	9·11	9·02	+15·4
CI Reactive Red 2	1	3/4	3	4	4·91	4·04	+0·5
	2	3/4	3	4	8·89	7·28	+1·9
	4	3	3	4	14·51	11·02	−0·2
CI Reactive Red 11	1	4	3/4	4	6·59	5·89	+12·6
	2	3/4	3/4	4	11·57	11·20	+7·8
	4	3/4	3/4	4	18·21	17·43	+7·9
CI Reactive Yellow 22	1	4/5	4/5	4/5	1·50	1·38	−2·2
	2	4	4/5	4/5	2·49	2·34	+7·7
	4	3/4	4/5	4/5	4·05	3·99	+11·3

TABLE 7
Wash Fastness Results for Dyeings Washed-off using Water at 60°C and Aftertreated using Matexil FC-ER

Dye	*% omf*	*Shade change*	*Staining of adjacent cotton*	*Staining of adjacent viscose*	K_1/S_1	K_2/S_2	$\Delta K/S$
CI Reactive Blue 163	1	3/4	4	4/5	4·02	3·69	+18·4
	2	3/4	4	4/5	6·30	6·17	+17·3
	4	3/4	3/4	4/5	12·22	11·80	+26·1
CI Reactive Blue 109	1	4	4/5	4/5	2·74	2·72	+12·1
	2	4	4/5	4/5	5·21	4·91	+12·8
	4	4/5	4/5	4/5	9·39	8·84	+13·7
CI Reactive Red 2	1	3/4	4	4/5	4·76	3·96	−2·3
	2	3/4	3/4	4/5	9·22	6·96	−2·6
	4	3/4	3/4	4	15·13	11·23	+1·7
CI Reactive Red 11	1	4	4	4/5	6·23	5·87	+12·3
	2	4	4	4/5	11·63	10·75	+4·0
	4	3/4	4	4/5	19·44	16·59	+4·0
CI Reactive Yellow 22	1	4/5	5	4/5	1·42	1·35	−3·7
	2	4	5	5	2·45	2·24	+3·6
	4	3/4	4/5	5	4·00	4·25	+3·0

TABLE 8
Wash Fastness Results for Dyeings Washed-off using Water at 80°C and Aftertreated using Matexil FC-ER

Dye	*% omf*	*Shade change*	*Staining of adjacent cotton*	*Staining of adjacent viscose*	K_1/S_1	K_2/S_2	$\Delta K/S$
CI Reactive Blue 163	1	4	4/5	4/5	3·94	3·89	+22·6
	2	3/4	4	4/5	7·07	6·08	+16·1
	4	3/4	4	4/5	11·95	11·68	+25·3
CI Reactive Blue 109	1	4/5	5	4/5	2·37	2·25	−6·2
	2	4	4/5	4/5	5·26	5·03	+14·9
	4	4	4/5	4/5	9·00	8·73	+12·6
CI Reactive Red 2	1	4	4	4/5	4·88	4·35	+6·9
	2	3/4	4	4/5	9·53	7·77	+8·1
	4	3/4	3/4	4/5	15·48	12·39	+10·9
CI Reactive Red 11	1	4	4/5	4/5	5·48	5·29	+2·6
	2	4	4	4/5	11·65	9·31	−10·8
	4	3/4	4	4/5	17·63	16·85	+5·5
CI Reactive Yellow 22	1	4/5	5	4/5	1·38	1·32	−6·1
	2	4	5	4/5	2·02	1·97	−9·6
	4	4	5	4/5	3·96	3·50	−0·8

TABLE 9
Wash Fastness Results for Dyeings Washed-off using Water at 98°C and Aftertreated using Matexil FC-ER

Dye	*% omf*	*Shade change*	*Staining of adjacent cotton*	*Staining of adjacent viscose*	K_1/S_1	K_2/S_2	$\Delta K/S$
CI Reactive Blue 163	1	4	4/5	4/5	3·72	3·72	+19·1
	2	3/4	4/5	4/5	6·22	6·22	+18·0
	4	3/4	4/5	4/5	11·15	10·90	+20·0
CI Reactive Blue 109	1	4/5	4/5	4/5	2·67	2·60	+8·1
	2	4/5	4/5	4/5	4·84	4·64	+7·8
	4	4	4/5	4/5	8·94	8·90	+14·3
CI Reactive Red 2	1	4	4	4/5	5·06	4·38	+7·5
	2	3/4	4	4/5	9·23	8·09	+11·7
	4	3/4	4	4/5	15·45	11·65	+5·2
CI Reactive Red 11	1	4/5	4/5	4/5	5·85	5·37	+4·1
	2	4	4	4/5	11·63	10·48	+1·5
	4	3/4	4	4/5	18·02	16·90	+5·8
CI Reactive Yellow 22	1	4/5	5	5	1·47	1·41	+0·7
	2	4	5	5	2·41	2·36	+8·4
	4	4	5	5	4·25	4·04	+12·4

TABLE 10
Wash Fastness Results for Dyeings Washed-off using Water at 20°C and Aftertreated using Matexil FC-PN

Dye	*% omf*	*Shade change*	*Staining of adjacent cotton*	*Staining of adjacent viscose*	K_1/S_1	K_2/S_2	$\Delta K/S$
CI Reactive Blue 163	1	3/4	3/4	4/5	3·36	2·60	−15·8
	2	3/4	3	4	5·50	4·02	−26·9
	4	3/4	3	4	8·95	7·57	−15·2
CI Reactive Blue 109	1	4	4/5	4/5	2·78	2·64	+9·5
	2	4	4/5	4/5	5·02	4·95	+13·5
	4	4	4	4/5	9·64	8·98	+15·0
CI Reactive Red 2	1	3/4	3/4	4	5·11	4·22	+4·0
	2	3/4	3/4	4	8·90	7·70	+7·3
	4	3/4	3	4	14·68	12·92	+14·5
CI Reactive Red 11	1	3/4	3/4	4	7·38	6·35	+18·9
	2	3/4	3/4	4	12·20	10·27	−0·5
	4	3/4	3	3/4	18·17	17·28	+7·9
CI Reactive Yellow 22	1	4	4	4/5	1·52	1·42	+1·4
	2	4	4	4/5	2·50	2·33	+7·3
	4	3/4	4	4/5	4·57	3·96	+10·6

TABLE 11
Wash Fastness Results for Dyeings Washed-off using Water at 60°C and Aftertreated using Matexil FC-PN

Dye	*% omf*	*Shade change*	*Staining of adjacent cotton*	*Staining of adjacent viscose*	K_1/S_1	K_2/S_2	$\Delta K/S$
CI Reactive Blue 163	1	4	4	4/5	4·37	3·99	+24·6
	2	4	4	4/5	6·86	6·59	+22·6
	4	4	4	4/5	11·43	10·99	+20·6
CI Reactive Blue 109	1	4	4/5	4/5	2·62	2·60	+8·1
	2	4	4/5	4/5	5·07	4·71	+9·1
	4	4	4/5	4/5	9·29	9·08	+16·0
CI Reactive Red 2	1	4	4	4/5	4·31	4·00	−1·2
	2	4	3/4	4/5	8·15	7·13	−0·1
	4	4	3/4	4	14·31	12·50	+11·7
CI Reactive Red 11	1	4	4	4/5	5·68	5·25	+1·9
	2	4	4	4	11·69	10·63	+2·9
	4	4	3/4	4	19·21	18·79	+15·3
CI Reactive Yellow 22	1	4/5	4/5	4/5	1·56	1·50	+6·7
	2	4/5	4/5	4/5	2·58	2·43	+11·1
	4	4/5	4	4/5	4·40	4·25	+16·7

TABLE 12
Wash Fastness Results for Dyeings Washed-off using Water at 80°C and Aftertreated using Matexil FC-PN

Dye	*% omf*	*Shade change*	*Staining of adjacent cotton*	*Staining of adjacent viscose*	K_1/S_1	K_2/S_2	$\Delta K/S$
CI Reactive	1	4	4/5	4/5	4·33	4·12	+25·0
Blue 163	2	4	4	4/5	7·05	6·82	+25·2
	4	4	4	4/5	12·69	11·45	+23·8
CI Reactive	1	4	4/5	4/5	2·76	2·61	+8·4
Blue 109	2	4	4/5	4/5	5·03	4·89	+12·5
	4	4	4	4/5	9·15	9·10	+16·1
CI Reactive	1	4	4	4/5	4·35	3·86	−4·9
Red 2	2	4	4	4/5	7·36	7·10	−0·6
	4	4	3/4	4	14·91	11·41	+3·2
CI Reactive	1	4	4	4/5	5·54	5·53	+6·9
Red 11	2	4	4	4/5	10·86	10·86	+5·0
	4	4	3/4	4	17·70	16·34	+2·6
CI Reactive	1	4/5	4/5	4/5	1·49	1·41	+0·7
Yellow 22	2	4	4	4/5	2·43	2·40	+10·0
	4	4	4/5	4/5	4·05	4·02	+11·9

TABLE 13
Wash Fastness Results for Dyeings Washed-off using Water at 98°C and Aftertreated using Matexil FC-PN

Dye	*% omf*	*Shade change*	*Staining of adjacent cotton*	*Staining of adjacent viscose*	K_1/S_1	K_2/S_2	$\Delta K/S$
CI Reactive	1	4	4	4/5	2·71	2·30	−34·3
Blue 163	2	4	4	4/5	3·91	3·46	−47·4
	4	4	4	4/5	6·55	5·94	−46·8
CI Reactive	1	4/5	4/5	4/5	2·51	2·42	+1·2
Blue 109	2	4	4/5	4/5	4·35	4·25	−0·7
	4	4	4/5	4/5	8·45	8·32	+8·3
CI Reactive	1	4	4	4/5	4·26	3·98	−1·8
Red 2	2	4	4	4/5	8·00	7·41	+3·6
	4	4	4	4/5	13·81	11·34	+2·6
CI Reactive	1	4	4	4/5	6·06	5·87	+12·1
Red 11	2	4	4	4/5	11·34	11·34	+9·0
	4	4	3/4	4	18·37	18·06	+11·8
CI Reactive	1	4/5	4/5	4/5	1·33	1·30	−7·7
Yellow 22	2	4/5	4/5	4/5	2·22	2·07	−4·3
	4	4	4/5	4/5	3·87	3·79	+6·6

Tables 2–5 reveals that aftertreatment with each of the cationic fixing agents generally resulted in an improvement of wash fastness of the dyeings. Furthermore, the extent of this improvement in wash fastness imparted by each fixing agent increased as the temperature (severity) of the wash-off method increased. This latter finding can be explained in terms of the amount of unfixed dye present in the dyeings. Previously, the results in Tables 2–5 showed that the amount of unfixed dye removed from the dyed samples by wash-off with water increased with increasing severity of the wash-off method. Thus, because the amount of unfixed dye present in the aftertreated dyeings that is available for desorption during subsequent wash testing will decrease with increasing severity of the wash-off method used, the fastness of the aftertreated dyeings should increase with increasing severity of the water wash-off method used, as was indeed found (Tables 6–13).

A comparison of Tables 6–9 and Tables 10–13 reveals that aftertreatment with Matexil FC-PN imparted a greater improvement in wash fastness than aftertreatment with Matexil FC-ER. As details of the composition of these two products are not available,[4] no explanation for this finding can be proferred. It is also evident from Tables 1, 6–9 and also 10–13, that in the case of the dyeings that had been washed-off using water at 80°C and 98°C, aftertreatment with the two cationic fixing agents resulted in wash fastness ratings that were either identical to or only one-half point lower than comparable depth dyeings which had been washed-off using detergent.

The $\Delta K/S$ values recorded in Tables 6–13 show that, with relatively few exceptions, the colour strength of the washed dyeings that had been washed-off using water and aftertreated with the two cationic fixing agents, was greater than that of comparable depth, washed dyeings that had been washed-off using detergent. Thus, whilst the wash fastness ratings achieved for the aftertreated dyeings that had been washed-off using water (Tables 6–13) were lower than those of their counterparts which had been washed-off using detergent (Table 1), the final colour strength (depth of shade) of the former dyeings was higher.

CONCLUSIONS

The results demonstrate that none of the four water-based wash-off methods used resulted in the dyeings achieving a level of fastness that was as high as that achieved using the detergent-based wash-off method. Thus, none of the water-based wash-off methods was as effective as the detergent-based method in removing unfixed dye from the dyed fabric.

Aftertreatment, with each of the cationic fixing agents, of the dyeings which had been washed-off using the four water-based methods resulted in an improvement of wash fastness of the dyeings. Furthermore, the extent of this improvement in wash fastness imparted by each fixing agent increased as the temperature (severity) of the wash-off method increased. Aftertreatment with matexil FC-PN imparted a greater improvement in wash fastness than aftertreatment with Matexil FC-ER. In the case of dyeings that had been washed-off using water at 80°C and 98°C, after-treatment with the two cationic fixing agents resulted in wash fastness ratings that were either identical to or only one-half point lower than comparable depth dyeings which had been washed-off using detergent. The finding that, with relatively few exceptions, the colour strength of the washed dyeings that had been washed-off using water and aftertreated with the two cationic fixing agents was greater than that of comparable depth, washed dyeings that had been washed-off using detergent indicates that whilst the wash fastness ratings achieved for the aftertreated dyeings that had been washed-off using water were lower than their counterparts which had geen washed-off using detergent, the final colour strength of the former dyeings was higher.

REFERENCES

1. Fox, M. R. & Sumner, H. H., In *The Dyeing of Cellulosic Fibres*, ed. C. Preston. Society of Dyers and Colourists, Bradford, 1986.
2. *Chemical Auxiliaries for the Textile Industry, CAFT 4(R)*, ICI Surfactants, Wilton, Middlesborough, 1990.
3. ICI Technical Information Pamphlet PL229, Manchester, 1984.
4. *Standard Methods for the Determination of the Colour Fastness of Textiles and Leather*, 5th edn. Society of Dyers and Colourists, Bradford, 1990.
5. Baldwinson, T. M., In *Colorants and Auxiliaries*, ed. J. Shore. Society of Dyers and Colourists, Bradford, 1990, Vol. 2.
6. Kramrisch, B., In *The Dyeing of Cellulosic Fibres*, ed. C. Preston. Society of Dyers and Colourists, Bradford, 1986.