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# Evaluation of the Stripping Performance of Monochlorotriazine/Vinyl Sulphone Reactive Dyes with a Reductive Stripping Agent

*Ocena učinkovitosti razbarvanja monoklorotriazin/vinilsulfonskih reaktivnih barvil z redukcijskim razbarvalnim sredstvom*

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## Abstract
The wet processing industry experiences various problems, such as the faulty and uneven shade of dyeing, colour patch formation on the surface of dyed fabric, etc. during the dyeing and subsequent processing of textile materials. Stripping is considered a process that helps to reuse faulty dyed fabrics by minimizing dyeing faults. The aim of this paper is to evaluate the effectiveness of stripping agents and the quality of stripped cotton knit fabrics that were coloured using bi-functional (monochlorotriazine/vinyl sulphone) reactive dyes. First, the trichromatic combination of Drimarene Yellow CL2R, Drimarene Red CL5B and Drimarene Blue HFRL dyes was used to dye fabrics in two different shade percentages, namely light shade (0.3% owf) and dark shade (3.0% owf). Consequently, stripping was carried out using varying concentrations of stripping chemicals (hydrose ($Na_2S_2O_4$) and caustic soda (NaOH)) and process temperatures. Stripped fabrics were assessed after measuring the weight loss percentage, strength loss percentage, whiteness index and stripping efficiency. The results of that assessment showed a relatively better stripping performance with the chemical concentration of 5 g/L hydrose and 5 g/L caustic soda at 100 °C. Under this condition, the value of the whiteness index and stripping efficiency were adequate, with a minimum weight loss percentage and strength loss percentage. The stripping performance for the light shade (0.3% owf) fabric was deemed to be better than that for the dark shade (3.0% owf) fabric.
Keywords: reactive dye, reductive stripping, temperature, whiteness index, stripping efficiency

## *Izvleček*
*Industrija mokre obdelave se srečuje z raznolikimi težavami, kot so napačni in neenakomerni barvni odtenki, barvni madeži na površini obarvanega blaga in težavami, ki nastanejo med barvanjem in poznejšo obdelavo tekstilnih materialov. Razbarvanje je postopek, ki zmanjša napako pri barvanju in s tem omogoči ponovno uporabo barvanega blaga. Namen tega članka je oceniti učinkovitost sredstev za razbarvanje in kakovost razbarvanih bombažnih pletiv z uporabo bifunkcionalnih (monoklorotriazinskih/vinil sulfonskih) reaktivnih barvil. Prvič je bila za barvanje pletiv v dveh različnih odtenkih uporabljena trikromatska kombinacija barvil Drimarene Yellow CL2R, Drimarene Red CL5B in*

*Drimarene Blue HFRL, in sicer za svetli odtenek 0,3 % barvila na maso pletiva in za temni odtenek 3,0 % barvila na maso pletiva. Zato je bilo razbarvanje izvedeno z različnimi koncentracijami sredstev za razbarvanje (natrijev hidrosulfit in natrijev hidroksid) in spreminjanjem temperature postopka. Razbarvana pletiva so bila ocenjena glede na odstotek zmanjšanja mase, odstotek znižanja trdnosti, indeksa beline in učinkovitosti razbarvanja. Ugotovljena je bila relativno boljša učinkovitost razbarvanja s koncentracijo 5 g/L natrijevega hidrosulfita in 5 g/L natrijevega hidroksida pri 100 °C. Pri teh pogojih sta bili vrednosti indeksa beline in učinkovitosti razbarvanja ustrezni ob minimalnem odstotku zmanjšanja mase in trdnosti. Učinkovitejše razbarvanje je bilo doseženo pri pletivu s svetlim odtenkom (0,3 % barvila na maso pletiva) kot pri pletivu s temnim odtenkom (3,0 % barvila na maso pletiva).*
*Ključne besede: reaktivno barvilo, reduktivno razbarvanje, temperatura, indeks beline, učinkovitost razbarvanja*

## 1 Introduction

Reactive dyes are one of the versatile classes of dyes containing a reactive group that makes a covalent bond with the terminal hydroxyl group (-OH) of cellulosic fibres, and act as an integral part of the fibre [1–3]. Textile companies use over 10,000 different classes of synthetic dyes for colouring numerous materials with a production of over $7 \times 10^5$ metric tonnes every year [4–6, 8]. During the dyeing and finishing of textile products, certain common faults are typically found, including uneven dyeing, inappropriate dyeing and the formation of colour patches on the fabric surface [6–8]. During the colouration process of cellulosic fibres with reactive dyes, undesirable errors and accidents occur, such as colour dots, different colour hues, and off shades that decrease fabric quality and value significantly. Various methods such as direct levelling, lightening with auxiliaries, re-dyeing in deeper shades or colour stripping can be employed to rectify dyeing faults. These dyeing faults can be overcome using the chemical stripping process of reactive dyes. Though dyeing faults can be removed by the stripping process, this process is comparatively difficult due to the presence of the covalent bond formed between the fibre and reactive dyes. Stripping is thus one of the reduction processes that can be used to reduce the concentration of dye in dyed fabric. These processes are also known as "destructive stripping" or "back stripping". In destructive stripping, colours are chemically reduced, while only the depth of shade is altered in back stripping. The stripping process aims to break the bonds between the chromophoric groups and the bridging groups of reactive dyes that are bonded with the cellulosic fibres through the reactive group, and thus creates discolouration [9]. For reduction purposes, strong reducing agents are used, which are electro-positive elements that can lose electrons in chemical reactions, known as electron donors. An atom with a relatively large atomic radius tends to be a better reductant or reducing agent. In such elements, the distance from the nucleus to the valence electrons is so long that these electrons are not strongly attracted. This type of element, such as hydrose, also tends to be a strong reducing agent for reductive stripping. The presence of caustic soda in a boiling solution under a suitable alkaline medium is created, and the alkaline aqueous solution helps hydrose to accelerate the release of nascent hydrogen. This nascent hydrogen attracts the covalent bond between the cotton fibre and reactive dyes, which is mainly responsible for the effective completion of the reducing reaction of the stripping process [8, 9]. Chemical reduction of an azo group (-N=N-) to an almost colourless amine derivative is possible in the case of destructive stripping [6, 8]. Chromophore groups of reactive dyes can be reduced, and an attempt is made to break chemical bonds to remove colours from fabric [10]. In order to increase the effectiveness of a reducing agent's ability to remove dyes from fabric and reduce reactive dyes, a stripping assistant is incorporated in addition to reducing agents [8]. The purpose of using a reducing agent is to promote the reduction process for the removal of fixed dyes from fabric, while a stripping assistant helps to promote the reduction capacity. A variety of combinations of reducing agents and stripping assistants are used to strip the dye from fabric [8]. The type of dyes, fibres, reducing agents, auxiliaries, stripping assistants and significant processing parameters (time, temperature, and pH) basically regulate the mechanism of reductive stripping. For a proper reduction effect, the use of appropriate time and temperature is mandatory. Treating fabric in a boiling alkaline solution is necessary to ensure an effective stripping process. Without boiling an alkaline solution, stripping cannot be completed effectively. That is why a temperature of 100 °C is employed. By conducting the stripping process at 80 °C, an attempt was made to determine whether the stripping of fabric could be carried out properly at a lower temperature or not [10]. In this work, stripping is carried out at temperatures of 80 °C and at 100 °C separately. Reactive dyes cannot be adequately removed from cellulose base fabric because a covalent bond has formed between the dye and fibre [8, 9]. The quality of the fabric is impacted and occasionally produces a harsh handle when high temperatures are used in alkaline reductive stripping [6].

By adjusting the reducing agent, alkali level and temperature, the author of one study report demonstrated the impact of reductive stripping on the quality of cotton fabric that was coloured using reactive dyes [7]. Another author discussed in detail an analysis of the performance of stripping chemicals on bi-functional reactive dyes [6]. The chemical colour stripping of cellulosic fabric dyed using reactive dyes has been shown in certain other studies. In this research work, the identical nature of reactive dye was used to produce a combination shade, while different shade percentages were used for dyeing fabrics to establish stripping processes. In addition, the whiteness index of stripped fabrics was assessed in this work, which was not found in other related studies. The aim of this study was to develop more effective stripping processes and to investigate the optimum concentration of reducing agents and temperature, and to assess the impact of stripping on the quality of dyed cotton fabric [7].

## 2 Materials and methods

### *2.1 Materials*

Single jersey cotton fabric of 152 g/m$^2$ was selected to carry out the assessment. The pre-treated (scoured and bleached) fabric samples were sourced from Epyllion Knittex Limited, Banglabazar, Gazipur. Three distinct reactive dyes – Drimarene Yellow CL2R, Drimarene Red CL5B, and Drimarene Blue HFRL – were used to produce trichromatic shades for the assessment process and gathered from Archroma (Bangladesh) Limited. Auxiliary chemicals for the dyeing and stripping process, such as Dekol 1097 (sequestering agent), Leonil EH (wetting agent), Glauber's salt ($Na_2SO_4 \cdot 10\ H_2O$), soda ash ($Na_2CO_3$), acetic acid ($CH_3COOH$), hydrose ($Na_2S_2O_4$), and caustic soda (NaOH), were also supplied by the same supplier for research purposes.

### *2.2 Dyeing process*

The pre-treated fabric was dyed with a trichromatic combination to produce a light shade (0.3% owf) and a dark shade (3.0% owf), using the exhaust method in an IR sample dyeing machine for 40 minutes at a temperature of 60 °C. The liquor ratio of the sample was maintained at 1:30, while the pH value of the dye bath was 10.5 during dyeing process. The study continued using the hot wash method after the dyeing process, and the specimens went through the neutralization process with 1cc/L of acetic acid for five minutes and the soaping process with 1 g/L of Dekol SN for five minutes at a temperature of 80 °C. The dyeing of pre-treated fabric was carried out according to the recipe given in Table 1 and using the dyeing curve in Figure 1.

*Table 1: Recipe of the dyeing process to produce light shade (0.3% owf) and dark shade (3.0% owf) fabric using reactive dyes*

| No. | Shades of the dyed fabric | | | Dyeing auxiliaries | | | |
|---|---|---|---|---|---|---|---|
| | Dyes | Combined shade (%owf) | Individual shade (%owf) | Glauber's salt(g/L) | Soda ash(g/L) | Wetting agent (cm$^3$/L) | Sequestering agent(cm$^3$/L) |
| 1 | Drimarene Red CL5B | 0.3 | 0.1 | 20 | 12 | 1 | 1 |
| | Drimarene Yellow CL2R | | | | | | |
| | Drimarene Blue HFRL | | | | | | |
| 2 | Drimarene Red CL5B | 3.0 | 1.0 | 60 | 18 | 1 | 1 |
| | Drimarene Yellow CL2R | | | | | | |
| | Drimarene Blue HFRL | | | | | | |

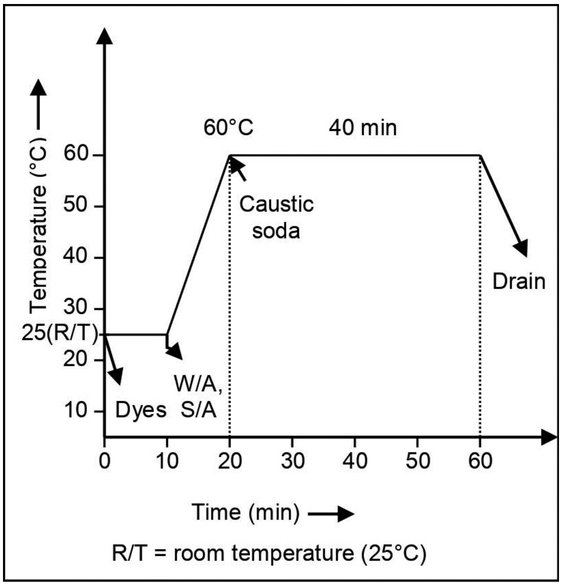



Figure 1: Time-temperature curve of dyeing

### 2.3 Stripping process

The assessment of the stripping performance of eight different variations of stripping recipes was performed for each shade percentageusingan IR exhaust sample dyeing machine with a material-to-liquor ratio of 1:40. The timeframe required for the stripping operation was 30 minutes. Details regarding the recipes used for the stripping process are given in Table 2, while the stripping curve is shown in Figures 2 and 3.

### 2.4 Assessment of fabric quality

*Measurement of weight loss percentage*

The reduction of fabric weight after stripping five-grams of fabric sample was calculated by examining the weight of the fabric before and after the stripping process. Weight reduction after the stripping process was measured using equation 1 [11].

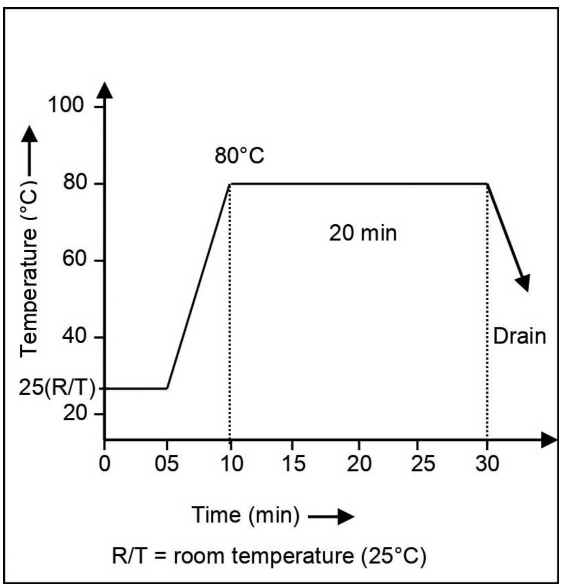



Figure 2: Time-temperature curve of stripping (80 °C)

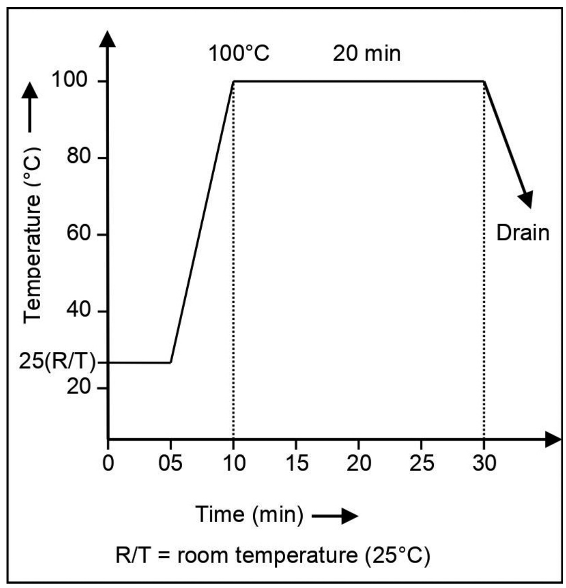



Figure 3: Time-temperature curve of stripping (100 °C)

$$\text{Weight loss} = \frac{(\text{Fabric weight before stripping - Fabric weight after stripping})}{\text{Fabric weight before stripping}} \times 100\ (\%) \quad (1)$$

*Measurement of fabric strength loss percentage*

The strength loss of the stripped fabrics was evaluated by a bursting strength tester, which was an indicator of the effectiveness of the stripping process. The bursting strength of the dyed and striped fabric was evaluated using ISO 13938-1:1999. Calculation of the bursting strength loss of the stripped fabric was executed by the following mentioned equation 2 [11].

$$\text{Strength loss} = \frac{(\text{Fabric strength before stripping - Fabric strength after stripping})}{\text{Fabric strength before stripping}} \times 100\ (\%) \quad (2)$$

*Table 2: Recipe of the stripping process with reductive stripping chemicals*

| No. | Temperature used in process (°C) | Concentration of hydrose (g/L) | Concentration of caustic soda (g/L) |
|---|---|---|---|
| 1 | 80 | 5 | 2.5 |
| 2 | | 5 | 5 |
| 3 | | 10 | 5 |
| 4 | | 10 | 10 |
| 5 | 100 | 5 | 2.5 |
| 6 | | 5 | 5 |
| 7 | | 10 | 5 |
| 8 | | 10 | 10 |

The consequence of strength loss due to stripping in the fibre surface was visualized using scanning electron microscope (SEM) images for the dyed and stripped fabrics of the light shade (0.3% owf) and the dark shade (3.0% owf) at a magnification of 500x.

The strength factor with respect to hydroxyl groups (-OH) was determined by Fourier transform infrared (FTIR) using PerkinElmer FTIR instrument model MB 3000 manufactured by ABB Canada.

*Assessment of whiteness index*

Whiteness is associated with the region in the colour space where objects are recognized as white. The whiteness index is measured by the degree of departure of the object from pure white [12]. It was measured using a Datacolor SF 600 dual-beam spectrophotometer in accordance with CIE (Commission internationale de l'éclairage) standards. The whiteness index of pre-treated fabric was 70.74 (WI-CIE) and whiteness index of stripped fabric was measured to assess the outcome of stripping.

*Stripping efficiency*

Stripping efficiency was assessed using the degree of colour removal from dyed samples. Lightness values ($L^*$) were measured using a Spectraflash SF600X machine in accordance with the method set out in the CIE standards, under a D-65 light source with the observer positioned at 10°. The stripping efficiency of dyed samples was calculated using equation 3 below [6].

$$\text{Stripping efficiency} = \frac{\text{Lightness value of stripped sample}}{\text{Lightness value of dyed sample}} \times 100\ (\%) \quad (3)$$

## 3 Results and discussion

After the assessment of all parameters of pre-treated, dyed, and stripped fabrics, data were recorded in Table 3. Those data indicate various findings including variation in weight loss percentage, strength loss percentage, whiteness index and stripping efficiency for light shade (0.3% owf) and dark shade (3.0% owf) stripped at two different temperatures 80 °C and 100 °C.

The stripped dyed samples were assessed according to the weight loss percentage, strength loss percentage, whiteness index and stripping efficiency. Of those samples, 18 were developed after dyeing, stripping and the assessment of qualitative parameters, such as whiteness index and stripping efficiency. The images of dyed and best-stripped fabric areshown in Figure 4.

### 3.1 Weight loss percentage of fabric due to stripping

Figures 5 and 6 illustrate the weight loss percentage of the stripped fabric of light shade (0.3% owf) and dark shade (3.0% owf), respectively. For both light shade (0.3% owf) and dark shade (3.0% owf) fabrics, the weight loss percentage increased linearly with an increase in the stripping chemical's concentration and stripping temperature. The highest weight loss percentage of the light shade (Figure 5) was determined at 100 °C, with a concentration of 10 g/L hydrose and 10 g/L caustic soda. The calculated weight loss percentage due to stripping at a temperature of 100 °C with the maximum concentration was higher than the weight loss percentage at a temperature of 80 °C with the minimum concentration. This occurs because the use of a high concentration of chemicals accelerates the weight loss percentage due to

*Table 3: indicates values of weight loss, strength loss of dyed and stripped fabrics, while thevalues of the whiteness index and stripping efficiency were given in Table by comparing the difference in the condition between pre-treated and stripped fabric*

| Combined shade | No. | Concentration of stripping chemicals (g/L) | Temperature (°C) | Weight loss (%) | Strength loss (%) | Whiteness index | Stripping efficiency (%) |
|---|---|---|---|---|---|---|---|
| 0.3% owf Light shade | 1 | H-5, C- 2.5 | 80 | 0.0 | 0.4 | 4.29 | 91.33 |
| | 2 | | 100 | 0.6 | 0.6 | 7.85 | 91.41 |
| | 3 | H-5, C-5 | 80 | 0.6 | 0.8 | 4.32 | 93.23 |
| | 4 | | 100 | 0.9 | 0.9 | 8.17 | 92.87 |
| | 5 | H-10, C-5 | 80 | 0.8 | 1.25 | 4.57 | 92.61 |
| | 6 | | 100 | 1.2 | 1.4 | 17.39 | 91.32 |
| | 7 | H-10, C-10 | 80 | 0.9 | 1.3 | 5.12 | 94.53 |
| | 8 | | 100 | 1.5 | 1.5 | 21.83 | 95.45 |
| 3.0% owf Dark shade | 9 | H-5, C- 2.5 | 80 | 0.6 | 4.5 | -11.12 | 69.88 |
| | 10 | | 100 | 0.8 | 5.2 | -7.71 | 78.26 |
| | 11 | H-5, C-5 | 80 | 0.9 | 5.66 | -10.72 | 73.32 |
| | 12 | | 100 | 1.1 | 6.5 | -7.53 | 73.81 |
| | 13 | H-10, C-5 | 80 | 1.2 | 6.66 | -9.0 | 72.54 |
| | 14 | | 100 | 1.4 | 7.5 | -6.62 | 72.44 |
| | 15 | H-10, C-10 | 80 | 1.3 | 7.2 | -8.36 | 78.46 |
| | 16 | | 100 | 1.6 | 7.7 | -4.54 | 79.79 |

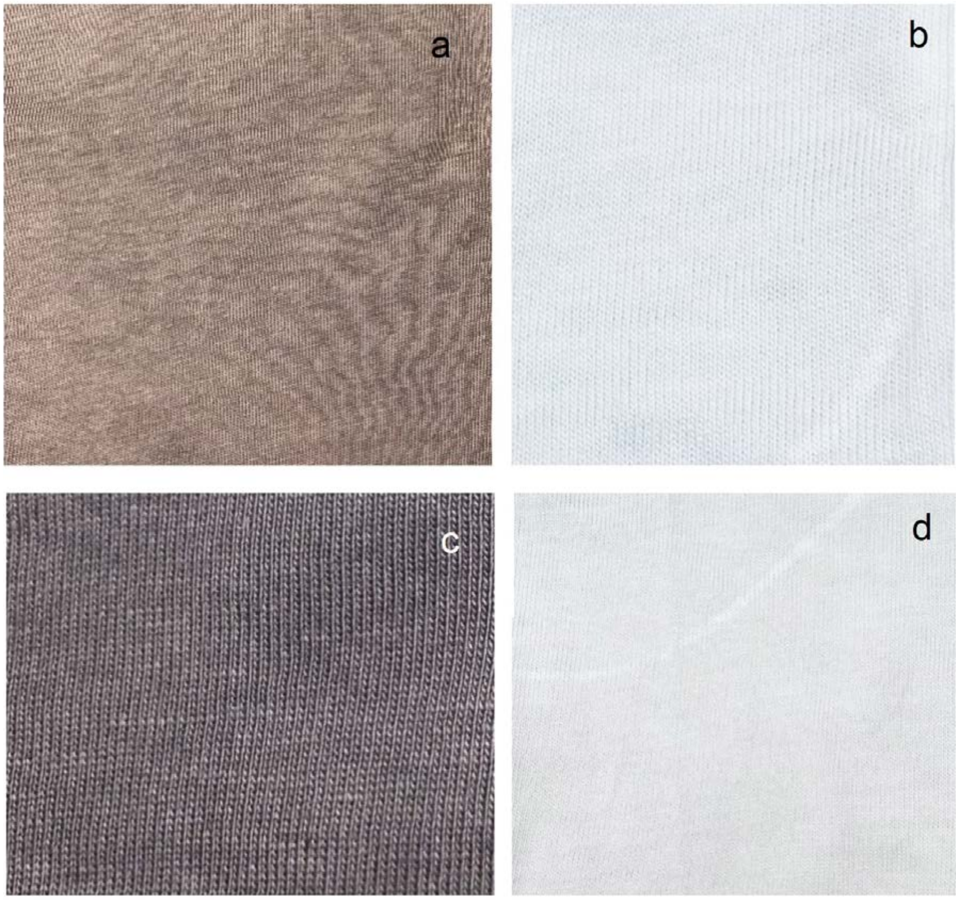



*Figure 4: Images of (a) dyed light shade (0.3% owf) fabric, (b) best-stripped light shade (0.3% owf) fabric, (c) dyed dark shade (3.0% owf) fabric, and (d) best-stripped dark shade (3.0% owf) fabric*

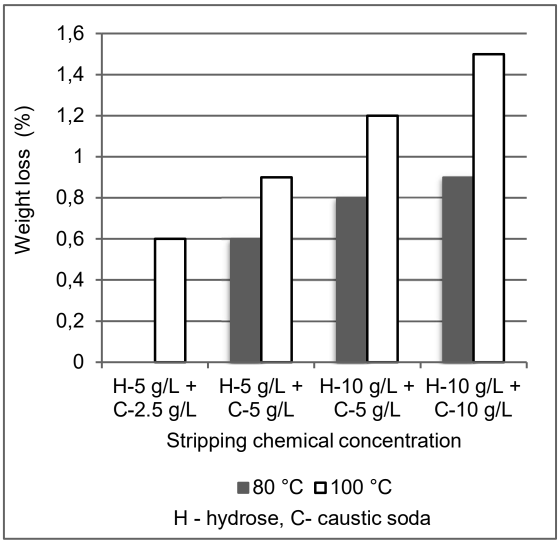



*Figure 5: Percentage of fabric weight loss for stripped light shade (0.3% owf) fabric*

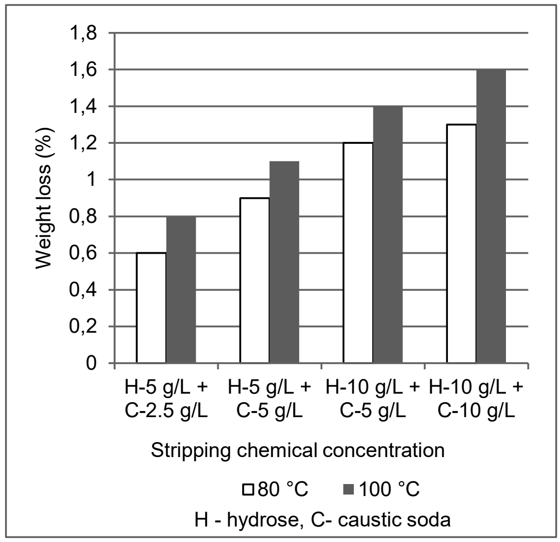



*Figure 6: Percentage of fabric weight loss for stripped dark shade (3.0% owf) fabric*

chemical effectiveness and an increase in temperature, and vice versa [13, 14]. Cotton fibre loses weight because the alcohol group that contains the glucose unit of the cellobiose unit (a repeating unit of cellulose) functions as a weak acid [8]. The maximum weight loss percentage was 1.5% and 1.6% for the light and dark shade fabric, respectively, using the highest concentration of stripping chemicals (10 g/L hydrose and 10 g/L caustic soda) at 100 °C. For the light and dark shade fabrics, the lowest weight loss percentage was 0% and 0.6%, respectively, using the lowest concentration of stripping chemicals (5 g/L hydrose and 2.5 g/L caustic soda) at 80 °C.

### 3.2 Strength loss of fabric due to stripping

Figures 7 and 8 illustrate the strength loss percentage of the stripped fabric of light shade (0.3% owf) and dark shade (3.0% owf), respectively. For both light shade (0.3% owf) and dark shade (3.0% owf) fabrics, the percentage of strength loss increased proportionally with an increase in the stripping chemical's concentration and stripping temperature. The highest strength loss percentage of the light shade (Figure 7) occurred with a concentration of 10 g/L hydrose and 10 g/L caustic soda at 100 °C temperature. The calculated strength loss percentage stripped at a temperature of 100 °C with

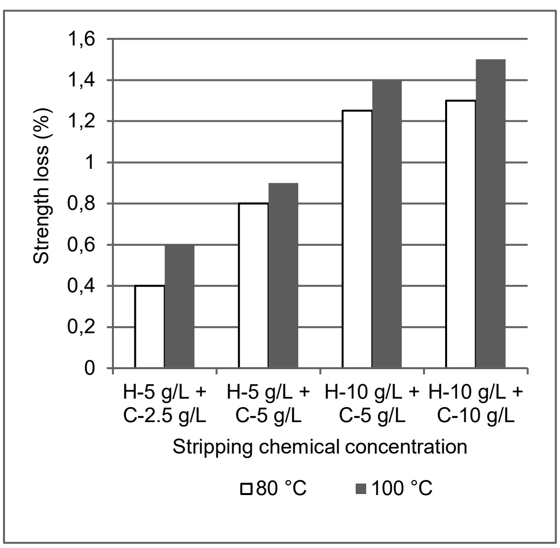



*Figure 7: Percentage of fabric strength loss for stripped light shade (0.3% owf) fabric*

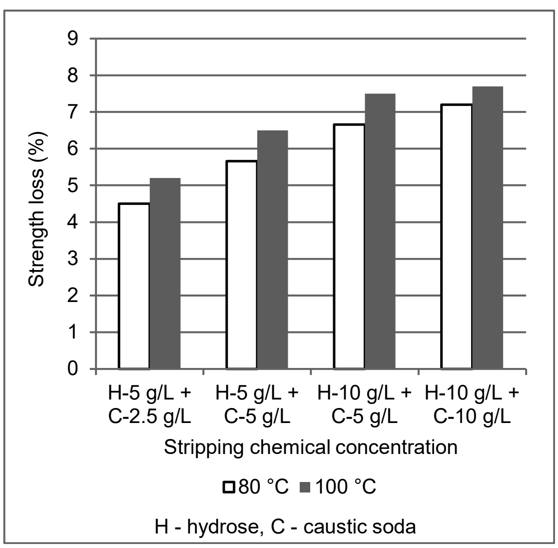


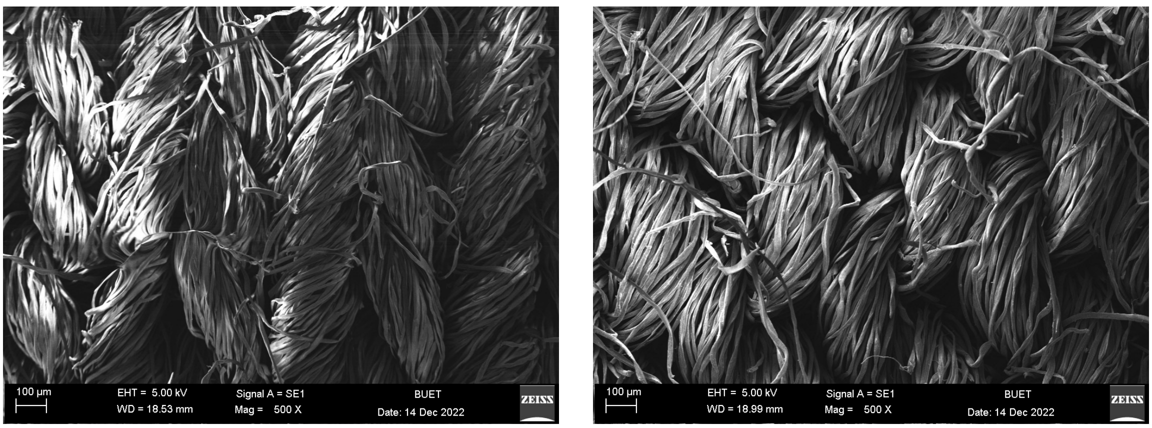

*Figure 8: Percentage of fabric strength loss for stripped dark shade (3.0% owf) fabric*

the maximum concentration was higher than the strength loss percentage at temperature of 80 °C with the minimum concentration. The use of a high concentration of chemicals reduces the bursting strength and damages the physical structure of fibre due to chemical effectiveness and an increase in temperature, and vice versa [13, 14].

SEM images were used to assess changes that occurred in the fibre surface after the stripping process. The SEM images presented in Figures 9a and 9b showed variations in the morphology of dyed (light shade 0.3% owf) and stripped fabric in which a magnification of 500× was used to examine the surface properties. The SEM images of light shade (0.3% owf) dyed fabric showed flat and smooth surface characteristics, spirally twisted ribbon-like fibre (Figure 9a), whereas the microfibril network of the stripped fabric remained disordered (Figure 9b). Stripped fabric showed a rougher surface than the dyed (light shade 0.3% owf) fabric. During the stripping process, the use of a reducing agent and sodium hydroxide (strong alkali) attacked the crystalline region of cotton. Consequently, swelling occurred due to increased amorphousness. This swelling effect caused the cotton fibre structure to open, while an untwisted condition was partially noticed (Figure 9b). Fibre damage occurred as a result.

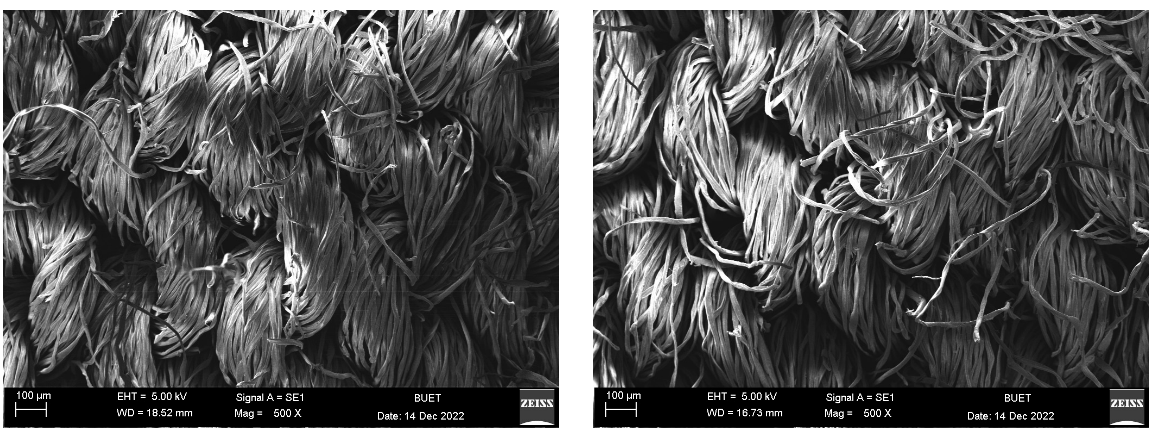
Similar effects were visualized by comparing Figure 10a and Figure 10b, which consecutively examined the surface properties of dyed (dark shade 3.0% owf) and stripped fabric at a magnification of 500×.

Swelling occurs in cotton in the presence of an alkaline solution during stripping. The crystalline region of cotton is converted to an amorphous region as the alkali acts as an intracrystalline swelling agent, resulting in the strength loss of cotton fibre when hydroxyl groups are reduced after stripping. Moreover, loss of strength occurs when strongly covalent bonded dyes with cotton are stripped from fibre with an aqueous solution of strong alkali under high temperatures. As a result, the alcohol




a) b)

*Figure 9: SEM images for light shade (0.3% owf) a) dyed fabric, and b) stripped fabric*




a) b)

*Figure 10: SEM images for dark shade (3.0% owf) a) dyed fabric, and b) stripped fabric*

group containing the glucose unit of the cellobiose unit (repeating unit of cellulose) acts as a weak acid. The strength of cotton fibre thus decreases [8].

FTIR analysis was performed for selected fabrics to analyze the presence of a hydroxyl group (-OH) in the dyed and stripped fabrics to justify the strength factor. The fabric with a higher stripping efficiency and whiteness index was chosen for FTIR stripped fabric analysis, where the chemical concentration of hydrose and caustic soda was 10 g/L each and the stripping temperature was 100 °C. The related light shade (0.3% owf) dyed fabric was chosen to perform the FTIR analysis of dyed fabric. The black line indicates the dyed fabric, and the additional coloured line indicates the stripped fabric in the FTIR spectrum in order to analyze absorbance.

Figures 11 represents the absorbance of IR radiation through the dyed fabric and stripped fabric for the analysis of the presence of an -OH group in the fabric. Here, the peak found in the range 3550–3200 $cm^{-1}$ wave number of the frequency region indicates the presence of -OH groups in the fabric. The graph shows higher and lower absorbance of IR for dyed and stripped fabric, respectively. Higher absorption indicates a strongly covalent bonded -OH group, which in turn indicates a higher amount of -OH group in the dyed fabric. On the other hand, lower absorbance was found in stripped fabric, indicating a weakly bonded -OH group in the fabric as -OH group significantly reduced after stripping.

The highest strength loss percentage was 1.5% and 7.7% for the light and dark shade fabrics, respectively, using a higher concentration of stripping chemicals (10 g/L hydrose and 10 g/L caustic soda) at 100 °C. The lowest strength loss percentages for the light and dark shade fabrics were 0.4% and 4.5%, by using a lower concentration of stripping chemicals (5 g/L hydrose and 2.5 g/L caustic soda) at 80 °C.

### *3.3 Assessment of whiteness index*

Figures 12 and 13 illustrate the whiteness index of the stripped fabric of light shade (0.3% owf) and dark shade (3.0% owf), respectively. For both light shade (0.3% owf) and dark shade (3.0% owf) fabrics, the whiteness index was raised by increasing the stripping chemical's concentration and stripping temperature. The highest whiteness index of the stripped light shade fabric (Figure 12) was 21.83, with a concentration of 10 g/L hydrose and 10 g/L caustic soda at 100 °C temperature. The whiteness index for stripping with the highest concentration was higher than the whiteness index with the lowest concentration of hydrose and caustic soda. A

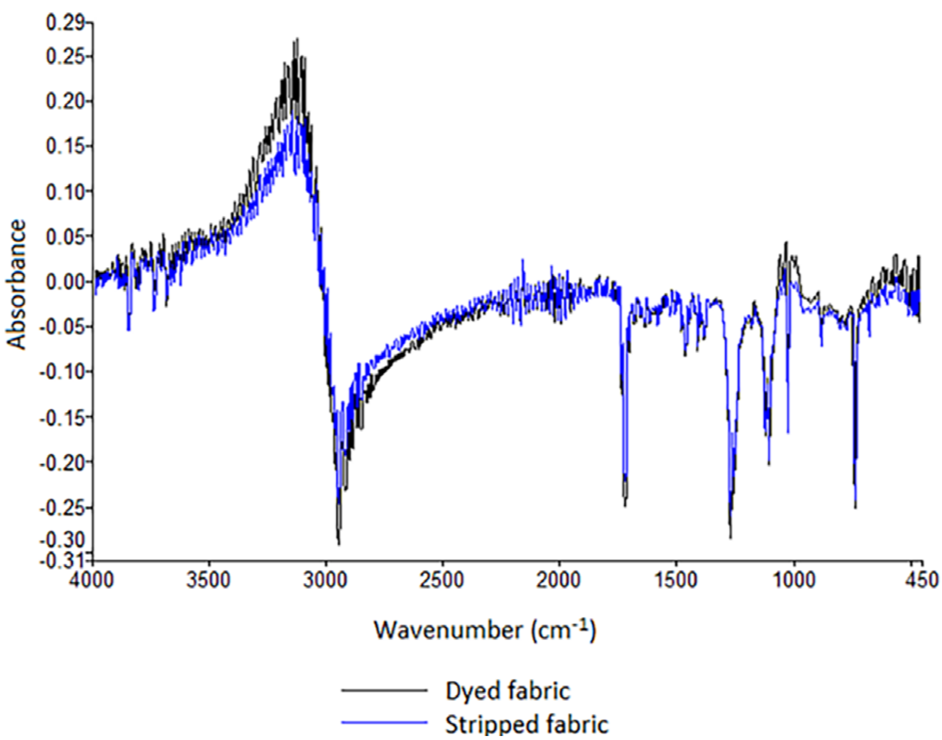



*Figure 11: FTIR examination of dyed and stripped fabric for analysis of absorbency*

change in temperature from low to high also affected the whiteness index slightly in the same manner. As the shade percentage of dyes in dark shade fabric was found to be higher, the whiteness index value for stripped dark shade fabric was lower than the stripped light shade fabric. Here, negative values of the whiteness index were seen for dark shade stripped fabric, where the values were lower at 80 °C than at 100 °C. The reason for this was the excessive reddish appearance of stripped fabrics at 80 °C relative to fabric at 100 °C, while stripping at 100 °C was found to be satisfactory. The highest whiteness index was 21.83 and -4.54 for the light and dark shade fabric, respectively, using a higher concentration of stripping chemicals (10 g/L hydrose and 10 g/L caustic soda) at 100 °C. The lowest whiteness index for the light and dark shade fabrics was 4.29 and -11.12, respectively, using a lower concentration of stripping chemicals (5 g/L hydrose and 2.5 g/L caustic soda) at 80 °C.

### 3.4 Assessment of stripping efficiency

Figures 14 and 15 illustrate the stripping efficiency of the stripped fabric of light shade (0.3% owf) and dark shade (3.0% owf), respectively. For both light shade (0.3% owf) and dark shade (3.0% owf) fabrics, stripping efficiency increased proportionally with an increase in the stripping chemical's concentration and stripping temperature. The highest stripping efficiency of the light shade (Figure 14) was 95.45%, with a concentration of 10g/L hydrose and 10 g/L caustic soda at 100 °C. The calculated stripping efficiency at 100 °C with the highest concentration of stripping chemicals was higher than the stripping efficiency at 80 °C with the lowest concentration of stripping chemicals. The use of a high concentration of chemicals increases the stripping efficiency due to chemical effectiveness and an increase in temperature, and vice versa [15]. For light-shade fabrics, the value of stripping efficiency was found to be higher because the light shade fabric absorbs less dyes than the darker shade of fabric. For this reason, the same concentration of stripping chemicals (hydrose and caustic soda) can easily strip out the colours from the light shade of fabric as it contains less dyes than the dark shade of fabric, and vice versa. From achieved values, it can be concluded that the stripping efficiency of the light shade (0.3% owf) stripped fabric was higher than the stripping efficiency of the dark shade (3.0% owf) stripped fabric. The highest stripping efficiency was 95.45% and 79.79% for the light and dark shade fabric, respectively, using the highest concentration of stripping chemicals (10 g/L hydrose and 10 g/L caustic soda) at 100 °C. The lowest stripping efficiency for the light and dark shade fabric was 91.33% and 69.88%, respectively, using the lowest concentration of stripping chemicals (5 g/L hydrose and 2.5 g/L caustic soda) at 80 °C.

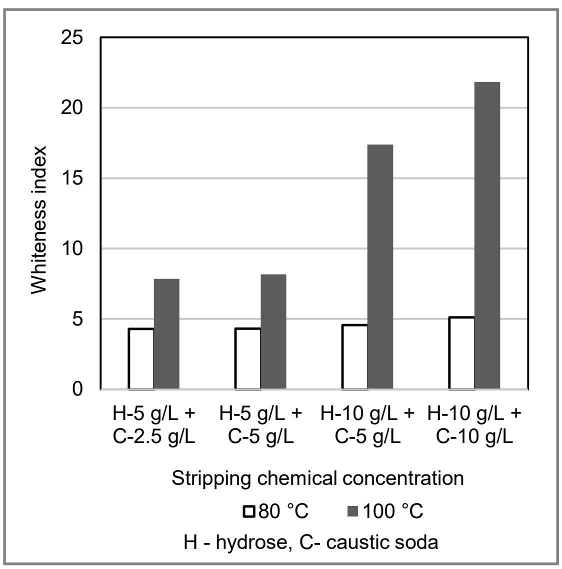



*Figure 12: Whiteness index of stripped light shade (0.3% owf) fabric*

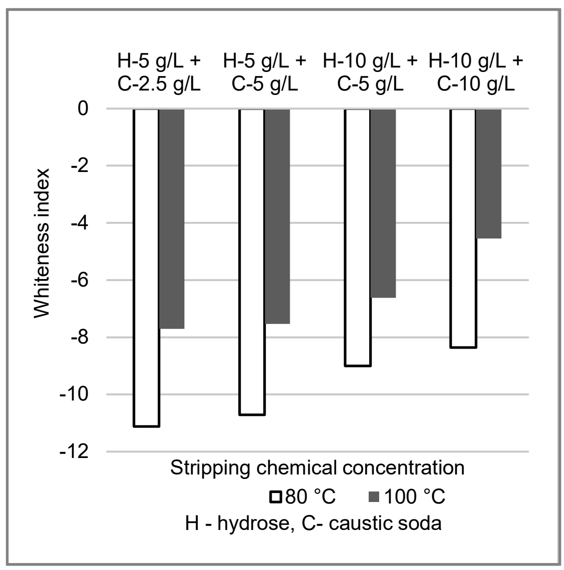



*Figure 13: Whiteness index of stripped dark shade (3.0% owf) fabric*

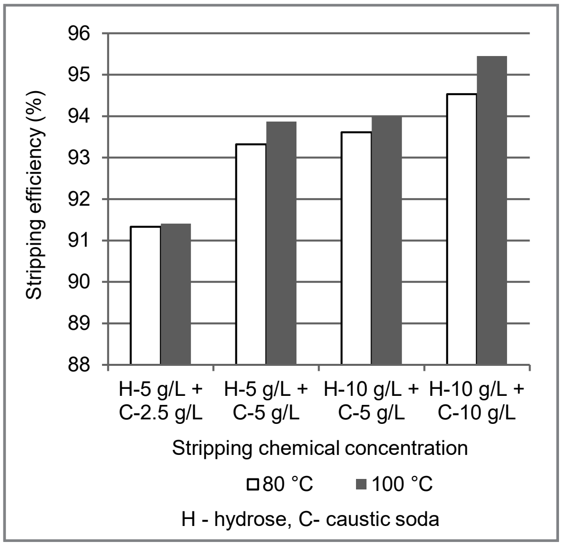



*Figure 14: Stripping efficiency of stripped light shade (0.3% owf) fabric*

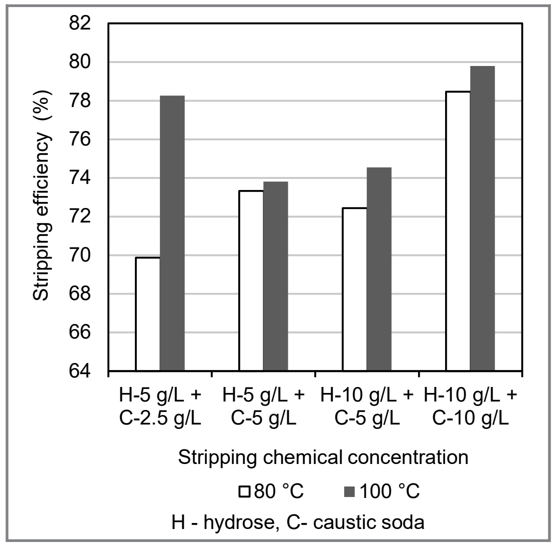



*Figure 15: Stripping efficiency of stripped dark shade (3.0% owf) fabric*

## 4 Conclusion

This work was carried out for the purpose of studying alkali reductive stripping in cotton knit fabric dyed with the Drimarene Yellow CL2R, Drimarene Red CL5B and Drimarene Blue HFRL reactive dyes, taking into account different concentrations of stripping chemicals (hydrose as reducing agent and caustic soda) and process temperatures as stripping parameters.

Increasing the stripping chemical concentration and process temperature resulted in a proportionate increase in the weight loss and strength loss percentage of the fabric. The dyed fabrics with shade percentages of 0.3% owf and 3.0% owf demonstrated maximum weight loss and strength loss percentage whenthey were treated with 10 g/L hydrose and 10 g/L caustic soda at 100 °C. The whiteness index values of light shade (0.3% owf) stripped fabrics were higher than that of dark shade (3.0% owf) stripped fabrics. Similarly, the stripping efficiency of the light shade (0.3% owf) stripped fabric was higher than that of dark shade (3.0% owf).

To maintain the good effects of stripping on fabric quality, it is recommended to use a lower concentration of stripping chemicals (5 g/L hydrose and 5 g/L caustic soda) at 100 °C. Stripping performances were improved by increasing the process temperature from 80 °C to 100 °C. The selection of standard process parameters can ensure an effective stripping process. As a result, the fabrics are readied for re-dyeing, which reduces the amount of waste and makes the textile and garment industry eco-friendlier and more sustainable.

## References

1. BURKINSHAW, S.M., SALIHU, G. The role of auxiliaries in the immersion dyeing of textile fibres: Part 6 analysis of conventional models that describe the manner by which inorganic electrolytes promote reactive dye uptake on cellulosic fibres. *Dyes and Pigments*, 2019, **161**, 595–604, doi: 10.1016/j.dyepig.2017.09.028.
2. HANBING, W., HAASE, H., MAHLTIG, B. Cationic pretreatment for reactive dyeing of cotton and its simultaneous antibacterial functionalisation. *Tekstilec*, 2020, **63**(1), 27–37, doi: 10.14502/Tekstilec2020.63.27-37.
3. LEWIS, D.M. Developments in the chemistry of reactive dyes and their application processes. *Coloration Technology*, 2014, **130**(6), 382–412, doi: 10.1111/cote.12114.
4. SLAMA, H. B., CHENARI BOUKET, A., POURHASSAN, Z., ALENEZI, F. N., SILINI, A., CHERIF-SILINI, H., OSZAKO, T., LUPTAKOVA, L., GOLIŃSKA, P., BELBAHRI, L. Diversity of synthetic dyes from textile industries, discharge impacts and treatment methods. *Applied Sciences*, 2021, **11**(14), 1–21, doi: 10.3390/app11146255.

5. ISLAM, M.R., MOSTAFA, M.G. Textile dyeing effluents and environment concerns - a review. *Journal of Environmental Science and Natural Resources*, 2019, **11**(1–2), 131–144, doi: 10.3329/jesnr.v11i1-2.43380.
6. GHOSH, N.C., FATEMA, U.K., MUNNI, A. Performance evaluation of stripping agents on bi-functional reactive dyes. *American Journal of Engineering Research (AJER),* 2018, **7**(2), 250–258, https://www.ajer.org/papers/Vol-7-issue-2/ZF070201250258.pdf.
7. ISLAM, M.M. Identification of different types of dyeing fault, causes and controlling method for quality and productivity. *International Research Journal of Modernization in Engineering Technology and Science*, 2021, **3**(4), 1147–1157.
8. UDDIN, M.G., ISLAM, M.M., ISLAM, M.R. Effects of reductive stripping of reactive dyes on the quality of cotton fabric. *Fashion and Textiles*, 2015, **2**(1), 1–12, doi: 10.1186/s40691-015-0032-y.
9. TAYYABA, N., YOUNAS, T., ALI, S. Chemical color stripping of cellulose fabric dyed with reactive dyes. *International Journal of Science and Innovative Research (IJESIR)*, 2021, **2**(5), 4–16, https://ijesir.org/wp-content/uploads/2021/ppp0100044IJESIR.pdf.
10. UDDIN, M.G., ISLAM, M.R. Evaluating the performance of alkali reductive stripping process of reactive dyes. *Journal of Fashion Technology and Textile Engineering*, 2015, **3**(2), doi: 10.4172/2329-9568.1000122.
11. KHAN, M.I., HOSNE, N., YEASIN, M., TURABI, H.A., RAIHAN, M.A.H., BISWAS, H. Dyeing of cotton fabric with different shade% of reactive dyes and different stripping condition to find out the maximum – minimum percentage of strength loss, weight loss, and pilling resistance of stripped fabric. *North American Academic Research (NAAR) Journal*, 2021, **4**(12), 163–179, doi: 10.5281/zenodo.5822854.
12. BERNS, Roy S. Numerical color specification: colorimetry. In *Billmeyer and Saltzman's Principles of Color Technology*. Hoboken : Wiley, 2019, 51–84, doi: 10.1002/9781119367314.ch4.
13. ASGHER, M., MUZAMMIL, M., QAMAR, S.A., KHALID, N., BILAL, M. Environmentally friendly color stripping of solar golden yellow R dyed cotton fabric by ligninolytic consortia from *Ganoderma lucidum* IBL-05. *Case Studies in Chemical and Environmental Engineering*, 2020, **2**, doi: 10.1016/j.cscee.2020.100031.
14. CHATHA, S.A.S., ASGHER, M., ALI, S., HUSSAIN, A.I. Biological color stripping: a novel technology for removal of dye from cellulose fibers. *Carbohydrate Polymers*, 2012, **87**(2), 1476–1481, doi: 10.1016/j.carbpol.2011.09.041.
15. OĞULATA, R.T., BALCI, O. Investigation of the stripping process of the reactive dyes using organic sulphur reducing agents in alkali condition. *Fibers and Polymers*, 2007, **8**, 25–36, doi: 10.1007/BF02908156.