1. Introduction

Bleaching is the most important pretreatment process commonly used in coloration industry for removing natural colorants and impurities of fiber prior to dyeing and finishing [1]. One of the oldest industrially bleaching chemicals is hypochlorite [2]. Although hypochlorite bleaching offers some advantageous effect, but it has been discouraged due to the formation of highly toxic chlorinated organic byproducts (AOX) during the bleaching process [3]. Another most important bleaching agent is hydrogen peroxide, which is commonly used for cellulosic fibers under alkaline conditions. The dissociation of hydrogen peroxide increased with rising temperature and form perhydroxyl anion shown in scheme 1[4].

Perhydroxyl ions (HO$_2^-$) demobilize the mobile electrons of conjugated double bonds in chromophores and caused decolorization [5]. However, hydrogen peroxide bleaching process required high temperature and long processing time, which leads to higher energy consumption and increased fiber damage [6].

$$\text{H}_2\text{O}_2 \rightarrow \text{H}^+ + \text{HO}_2^-$$

Scheme 1

The decomposition of H$_2$O$_2$ by the hydroperoxide anion provides per hydroxyl radical that oxidized the cellulose. In an alkaline solution, the perhydroxyl radical attacks the C$_2$ and C$_3$ atoms of cellulose, which form inactive carbonyls shown in scheme 2[7].

Peracetic acid (PAA) is well known strong

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# corresponding author: Kabir, Shekh M (E-mail: mamunkabir.butex@gmail.com)
oxidizing agent for its high reactivity. Therefore, it acts as good bleaching agents during mild process conditions [8]. Reaction of hydrogen peroxide with tetra-acetyl ethylene diamine can generate peracetic acid [9]. Application of PAA requires lower energy and water consumption during bleaching because it can perform at neutral pH without the addition of auxiliary agents [10]. PAA are environmentally friendly bleaching agents [11], because it contains –COOOH groups, which is fast acting, non-foaming, water soluble and non-advertising effects on polymer [12]. PAA with water exhibits an equilibrium reaction and contains acetic acid and hydrogen peroxide. Furthermore, the bleaching mechanism mainly occurred by epoxidation of the double bonds of impurities and natural colored compounds shown in scheme 3 [13].

\[
\text{CH}_3\text{COOOH} + \text{H}_2\text{O} \rightarrow \text{CH}_3\text{COOH} + \text{H}_2\text{O}_2 \\
\text{CH}_3\text{COOH} + \text{impurities} \rightarrow \text{CH}_3\text{COOH} + \text{oxidised impurities}
\]

Scheme 3

Several researches has been carried out about the PAA bleaching mechanism, kinetics and decomposition with the influence of temperature, pH and addition of catalyzing agents [14‒15]. Bio scouring and bleaching of cotton with PAA in one bath were accompanied by negligible fiber damage and uniform degree of whiteness [16]. The optimum cotton bleaching of PAA were obtained at 30 g/L and used in neutral or mildly alkaline conditions [17]. In addition, the satisfactory whiteness index (64) of cotton bleaching conditions with peracetic acid were investigated in the bleaching liquor from acetic anhydride and H\textsubscript{2}O\textsubscript{2} [12]. The structural changes in jute fibers with bleaching of PAA were analyzed by spectroscopy and crystalline changes were observed during treatment time [18]. The removal of lignin and pectin from hemp fibers were carried out by chemical processing was investigate [19]. Nevertheless, the influence of peracetic acid bleaching of hemp fiber were determined with 30 ml/L concentration. 90 minutes process time and 95°C process temperature for attaining highest whiteness value [20].

More recently, increasing environmental legislation, concern of environmental sustainability and the depletion of fossil fuels enhancing the demand of sustainable fashionable goods for consumers [21]. Nowadays natural cellulose-based fibers are increasingly gaining attention for diversified materials [22]. Jute fiber has recently been undergoing a revival worldwide because of its superior eco-friendly properties such as tensile strength, excellent thermal conductivity and coolness [23]. The chemical composition of jute fiber has been analyzed by numerous researchers, it contains cellulose (58~63%), hemi-cellulose (20~24%) and lignin (12~15%) and some other constituents like fats, pectin and aqueous extract [24]. Lignin and hemi-cellulose are cemented together and surrounded of jute cellulose structure that provides rigidity to the cell wall. The main shortcomings of jute fiber for producing wearable textile products are stiffness, coarseness, low extensibility and low grip performance due to lignin and impurities [25]. Blending is a technique to overcome the limitations of jute fiber and emphasizes the diversified wearable items. Jute-cotton blend (Juton) fabric have been carried out by improving process performance of the fibers, to impart fancy effect, improve functional properties and reduce cost of the product [26]. Coloration of Jute-cotton blend (Juton) fabric is quite challenging for dyers, because of non-cellulosic components and higher crystalline structure of jute fiber than cotton fiber. Therefore, wet chemical processing is essential to improve the dye ability of Jute-cotton blend (Juton) fabric [27]. The natural color of cotton is normally creamy-white [28]. However, jute fiber contains complex tannin compounds in cortical cells, which are the derivatives of chlorophyll, xanthophyll, carotene and its derivatives [29]. Different impurities like dust, oil, plant particles with natural coloring elements of Jute-cotton blend (Juton) blend fabrics are undesirable during dyeing and finishing. Producing light, medium and deep shades of Juton blend fabric, bleaching is essential for removing undesirable colorants and impurities [30]. Consequently, several researches have been carried out about the peracetic acid bleaching performance on cotton and hemp fibers according to whiteness index [31]. However, there has been no research conducted about the bleaching performance of Jute-cotton blend (Juton) fabric with color strength (f) for deep coloration.

The present study has investigated the performance of PAA and H\textsubscript{2}O\textsubscript{2} bleaching on Jute-cotton blend (Juton) fabric and compared with the results of color strength (f) over a range of bleaching temperatures, time, pH and concentration. Dye build-
up, color properties and color fastness were determined. Dye exhaustion and fixation were also measured for different bleached samples. In order to comprehend the physical and chemical changes on surface morphology were evaluated by tensile strength, elongation, weight loss (%), FT-IR and SEM images. Analyzing, the environmental effects of bleaching bath effluents were carried out by biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolve solids (TDS) and dissolve oxygen (DO).

2. Experimental

2.1 Materials

Plain woven greige Jute-cotton blend (Juton) fabric (GSM 360) composed from 8/1 Nm 80% jute yarns and 11 Ne 20% cotton yarns (50 yarn/inch warp, 25 yarn/inch weft) was used for bleaching applications. H₂O₂ of 35% (w/w) which is the most commonly used concentration was purchased from Sigma Aldrich and used without purification. PAA of 40% (w/w) which is commercially available concentration was also purchased from Sigma Aldrich. C. I. Reactive Blue 238 (Fig. 1) which is a bifunctional vinylsulphone azo dye having high extinction coefficients and exhaustion (%) was used for dyeing of Jute-cotton blend (Juton) fabric.

2.2 Alkali Scouring

For improving the hydrophilicity of the fabric, scouring was carried out using 5 g/L sodium hydroxide, 3 g/L soda ash and 1 g/L wetting agent at 95°C for 60 minutes at a material-to-liquor ratio of 1:20. Then the fabric was washed with warm water and subsequently neutralization step was applied using 1 ml/L acetic acid for 15 minutes at a material-to-liquor ratio of 1:20. Finally, the fabric was cold rinsed and air-dried.

2.3 Bleaching

In this study, two parallel sets of experiments were undertaken for bleaching. Exhaust bleaching operations were carried out at a material-to-liquor ratio of 1:20 for both PAA and H₂O₂ applications according to bleaching profile shown in Fig. 2. The rate of deep coloration for PAA (40% w/w) bleaching on Jute-cotton blend (Juton) fabric was monitored at different initial pH values (5, 6, 7, 8, and 9), different temperatures (60, 70, 80, 90 and 100°C), different time (30, 50, 70, 90 and 110 min) and different concentration (5, 10, 15, 20 and 25 g/L). The bleaching bath liquor ratio was 1:20 and disodium hydrogen phosphate (3 g/L) was used as buffering agent. Bleaching of scoured Jute-cotton blend (Juton) was performed in a Starlet dyeing machine (South Korea) at a frequency of 85 rpm. After reactive dyeing of different bleached conditions, optimum points were detected by the

![Fig. 1 C. I. Reactive Blue 238](image1)

![Fig. 2 Bleaching profile of Juton fabrics](image2)
evaluation of color strength ($f_k$). In the second set, the scoured Jute-cotton blend (Juton) fabric was bleached with H$_2$O$_2$ (35% w/w, Sigma Aldrich) under similar conditions in closed dyeing machines. In fact, sodium silicate (3 g/L) was used as peroxide stabilizer. The fabric was washed in hot water and rinsed twice in cold water after bleaching. The samples were air dried and conditioned at 20±2°C and 60±5% relative humidity.

2.4 Dyeing

A 50 ml dye bath suitable for selected bleached Jute-cotton blend (Juton) fabrics was dyed with C.I. Reactive Blue 238. Dyeing was performed in laboratory-dyeing machine (starlet dyeing machine, DLS-6000 and infrared) at a material-to-liquor ratio of 1:20 with the concentration 1% owf for 60 min at 60°C. In addition, 20 g/L Glauber’s salt and 10 g/L soda ash was added for dye exhaustion and fixation. On the other hand, for measuring the color properties of Juton fabric, different dye concentration (0.5, 1, 2, 4 and 6% owf) was used. After dyeing all the samples were rinsed with cold tap water and dried at room temperature.

2.5 Color measurement

The color strength ($f_k$) values of the dyed Jute-cotton blend (Juton) fabrics were measured using a spectrophotometer (Datacolor 650, USA, standard light D65; 10° standard observer, specular component included) interfaced with a personal computer. The K/S value was calculated from the sample reflectance ($R$):

$$ K/S = (1 - R_j)^2 / 2R $$

In addition, $f_k$ represents the color strength value as the sum of the weighted K/S values in the visible region of the spectrum, as follows in equation (1):

$$ f_k = \frac{\sum_{\lambda=400}^{700} (K \times w_{10,\lambda} \times f_{10,\lambda} + w_{10,\lambda} \times f_{10,\lambda})}{10} $$

Where $x_{10}$, $y_{10}$, and $z_{10}$ are the color-matching functions for a 10° standard observer at each wavelength (ISO 7724/1: 1984).

2.6 Measurement of dye exhaustion and fixation

The dye exhaustion and fixation of bleached fabrics were calculated by measuring the absorbance of the residual dye bath liquor. Dye exhaustion and fixation yields were determined by UV-Vis spectrophotometer (Cintra 2020, GBC, Australia). The percentage of dye exhaustion (E%) and fixation (F%) was calculated according to Eqn. (2) and (3), respectively.

$$ E(\%) = \left[1 - \frac{A_1}{A_0}\right] \times 100 \quad (2) $$

$$ F(\%) = \left[\frac{(A_0 - A_1 - A_2)}{A_0}\right] \times 100 \quad (3) $$

Where $A_0$ and $A_1$ are the absorbance of the dye solution at $\lambda_{max}$ before and after dyeing. $A_2$ is the absorbance of the dye-soaped solution with a nonionic surfactant.

2.7 FT-IR Spectroscopy

The determination of specific functional groups of PAA bleached and H$_2$O$_2$ bleached fabric was measured by FT-IR (IR Prestige 21, SHIMADZU, Japan). The samples were placed in ATR mode for number of scanning was carried out 50 times and the resolution power was 4 cm$^{-1}$. The recorded spectrum for each sample was the average of 4 scans.

2.8 Scanning electron microscopy

Scanning electron microscopy (SEM) of PAA bleached and H$_2$O$_2$ bleached fabric was investigated by (JSM 6490 LA, JEOL, USA). The microscope was normally operated in the secondary emission mode at 15 kV. The photographs of the samples were taken at a magnification of ×1000.

2.9 Determination of tenacity, crease recovery angle and weight loss (%)

For the measurement of tenacity of Jute-cotton blend (Juton) fabric was measured with Tensile strength tester model-13934-1 (Susstec, Germany) according to standard ISO 13934-1 method. Crease recovery angles were determined according to BS EN 22313: 1992 standard. After PAA and H$_2$O$_2$ bleaching the percentage of weight loss of the fabric was calculated using the following equation (3)-

$$ \text{Weight loss (\%)} = \left[\frac{(W_o - W_i)}{W_o}\right] \times 100 $$

Where $W_o$ and $W_i$ are the weights of Jute-cotton blend (Juton) fabric before and after bleaching respectively.

2.10 BOD, COD, TDS & DO Measurement

Measurements of Biological Oxygen Demand (BOD$_5$) and Chemical Oxygen Demand (COD) values (in mg O$_2$/L) of the effluents of bleaching baths were carried out by Method 5210 (B) and 5220 accordingly. On the other hand, total dissolve solids (TDS) and dissolved oxygen (DO) were measured based on standard methods 2540 and ASTM D888-12 accordingly.
2.11 Color fastness measurement

Color fastness was evaluated according to the respective international standards: fastness to washing, ISO 105-C06 (2010); fastness to rubbing, ISO 105-X 12 (2016); fastness to perspiration, ISO 105-E04 (2013); and fastness to light ISO 105-B02 (2013). The staining of the multifiber strips and the change in the shade of the dyed samples were assessed using grey scales (ISO 105-A02 and A03).

3. Results and Discussion

3.1 Effect of bleaching pH on color strength

Effect of pH on PAA and H₂O₂ bleaching for Jute-cotton blend (Juton) fabric was investigated at 90°C with 15 g/L concentration, treatment time 90 min and material-to-liquor ratio of 1:20. The changes on color strength (f*) of Jute-cotton blend (Juton) depending on pH at 90°C bleaching were summarized in Fig. 3. The bleaching effects of PAA and H₂O₂ enhanced the color strength. The color strength of PAA bleached Juton fabric was higher than that of H₂O₂ bleached Jute-cotton blend (Juton) fabric and PAA bleaching exhibits highest color strength (f* =120) at pH 7 [8,11].

Prabaharan et al. [8] explained that in neutral medium PAA released nascent oxygen and perhydroxyl (HO₂-). On the other hand, in an alkaline medium (pH 9), H₂O₂ bleached Jute-cotton blend (Juton) fabric and PAA bleaching exhibits highest color strength (f* =120) at pH 7 [8,11].

3.2 Effect of bleaching temperature on color strength

Fig. 4 shows the temperature effects on the dyeability of the bleached Jute fabric with PAA and H₂O₂. The highest color strength was obtained at 80°C. The increase in color strength with an increase in temperature could be attributed to the decomposition of PAA and H₂O₂. The stability of peracetic acid also depends on the temperature; it is stable and starts to decompose with increased temperature. The decomposition rate depend on the availability of per hydroxyl ions at higher temperature. The results in Fig. 4 indicates that PAA bleaching at 80°C shows highest color strength (f* = 119) and the color strength gradually decreased as the temperature increased up to 100°C. It can be explained that, if the decomposition rate were very rapid, the ions would escape into the atmosphere before they could bleach. On the other hand, H₂O₂ bleaching at 80°C shows lower color strength (f* = 98) than PAA bleaching. It can be explained that, the degradation of bleaching agent and its bleaching effect gets more aggressive on Jute-cotton blend (Juton) fabric by H₂O₂. Therefore, cellulose degradation is quite higher, which influence the less dye uptake on Jute-cotton blend (Juton) fabric.

3.3 Effect of bleaching time on color strength

Fig. 5 depicted the effects of peracetic acid and H₂O₂ bleaching time over a range of 30-110 minutes at 90°C. In general, there was an increasing trend on color strength (f*) in relation to an increase on bleaching duration for PAA bleaching. The optimum color strengths were obtained at 70 minutes for peracetic acid (f* =119) and 50 minutes for H₂O₂.
bleaching ($f_k = 97$). It can be explained that, bleaching operations with longer treatment time caused the cellulose chain cleavage and damages by conversion of hydroxyl groups into carboxyl and aldehyde groups. H$_2$O$_2$ bleaching performed lower color strength than PAA bleaching probably due to the chemical degradation of Juton fabric for the extensive treatment time. Therefore, the optimum bleaching operations for Juton fabric were found at 70 min for peracetic acid and 50 min for H$_2$O$_2$ bleaching agents.

3.4 Effect of bleaching agent concentration on color strength

Fig. 6 presented the effects of the bleaching agent concentration on dyeability of the Jute-cotton blend (Juton) fabric in terms of the ($f_k$) values. In this study, the effects of PAA and H$_2$O$_2$ concentration over a concentration range of 5‒25 g/L were analyzed. The optimum bleaching time for both the PAA and H$_2$O$_2$ were obtained at the concentration of 10 g/L in terms of color strength of dyed fabrics. The decomposition of H$_2$O$_2$ by the hydroperoxide anion provides per hydroxyl radical that oxidized the cellulose, which form inactive carbonyls shown in scheme 2 [7]. On the other hand, PAA bleaching decomposes peracetic acid and H$_2$O$_2$ (Scheme 1) which can cause the degradation of cellulose fibers. Therefore, PAA bleaching of Jute-cotton blend (Juton) fabric provided higher color strength compared to H$_2$O$_2$ bleaching as shown in Fig. 6.

3.5 Dye build-up properties for bleaching effects

The effect of the dye concentration used in the dyeing process was evaluated in the range of 0.5-6\% owf. As seen in Fig. 7, the color strength in terms of $f_k$ value increased with an increase in the dye concentration.

It is clearly observed that peracetic acid bleached Jute-cotton blend (Juton) fabric achieved a much deeper shade than H$_2$O$_2$ bleached Jute-cotton blend (Juton) fabric. The dye concentration was increased at 6\% owf; however, the state of equilibrium was not achieved. Moreover, the color strength of PAA bleached Juton was almost 1.2 times higher than that of H$_2$O$_2$ bleached Jute-cotton blend (Juton) fabrics. The color photographs of PAA or H$_2$O$_2$ bleached and dyed Jute-cotton blend (Juton) fabrics are shown in Table 1. This result demonstrated that, PAA bleaching agents were suitable for deep dyeing of Jute-cotton blend (Juton) fabric.

The CIELAB $a^*$ and $b^*$ coordinates of the PAA
and H2O2 treated dyed Jute-cotton blend (Juton) fabrics represented in Fig. 8. As the dye concentration increased, the CIELAB a* and b* coordinates approach the achromatic point for PAA bleached Juton fabric, which indicates the deep coloration properties of Jute-cotton blend (Juton) fabric. On the other hand, H2O2 bleached dyed Jute-cotton blend (Juton) fabrics observed CIELAB a* and b* coordinates approach far from achromatic point than PAA bleached Jute-cotton blend (Juton) fabric.

Dye exhaustion, fixation and whiteness index behaviors of the bleached Jute-cotton blend (Juton) fabric samples were shown on Table 2. PAA bleached Jute-cotton blend (Juton) fabric observed higher exhaustion (76%) and fixation (67%) than H2O2 bleached Juton fabric. It can be explained that, H2O2 bleached Juton fabric formed carboxyl and aldehyde groups in cellulose, which indicate the extent of damage during bleaching. The presence of damaged cellulose reduced reactive dye uptake. Natural color, wax and different impurities were removed by PAA bleaching and no significant cellulose damage occurred by this process.

Therefore, reactive dyes formed covalent bond with cellulosic structure, which enhanced the dye exhaustion and fixation. Although the best whiteness performance on Jute-cotton blend (Juton) fabric were attained by H2O2 bleaching agents. This means that hydrogen peroxide is strong oxidizing agent and formed perhydroxyl ion (HO2-) which demobilize the mobile electrons present in the systems of conjugated double bonds present in chromophores and thus decolorize the compounds [33,34]. However, the whiteness index level was found 58.20 for PAA bleaching agents, which seems to be commercially reasonable limits. Jute-cotton blend (Juton) fabrics exhibit brownish color with higher amount of natural colorants presence and as well as it contains higher cellulosic materials and impurities. Therefore, Jute-cotton blend (Juton) fabric needs more aggressive bleaching operations. From economic and environmental point of view, PAA bleaching agent has performed quite satisfactory level for Jute-cotton blend (Juton) fabric bleaching operations.

3.6 Chemical changes on bleached Jute-cotton blend (Juton) fabric

The FTIR (ATR) spectra of greige Jute-cotton blend (Juton) fabric (bleaching with 10 g/L bleaching agent at pH 7 for PAA and pH 9 for H2O2, 80°C for 70 min and dyeing at 60°C for 60 min)
blend (Juton) fabrics revealed in Fig. 9, using transmittance (%) versus wave number (cm⁻¹) where, hydrogen bonded of OH stretching in cellulose or hemicellulose absorbs (3000-3600 cm⁻¹), CH₂ stretching and CH stretching of cellulose and hemicellulose (2862 and 2935 cm⁻¹), C=O in-plane aromatic vibrations from lignin (1505 and 1595 cm⁻¹), carboxylic acid of pectin and C=O vibration (1800 cm⁻¹), CH bending of cellulose and hemicellulose (1375 cm⁻¹), CH₂ wagging of cellulose and hemicellulose (1315-1335 cm⁻¹) and antisymmetrical deformation of the C-O-C band (1160 cm⁻¹). The constancy of the FTIR-ATR spectra of greige, PAA and H₂O₂ bleached Jute-cotton blend (Juton) fabric suggested in Fig. 9 with some significant changes. It is clearly observed that CH₂ and CH stretching of cellulose and hemicellulose (2862 and 2935 cm⁻¹) and carboxylic acid of pectin and C=O vibration (1800 cm⁻¹) were absent into the H₂O₂ bleached fabric. Therefore, it can be explained that, perhydroxyl ions of H₂O₂ causes damage on cellulose and hemicellulose structure of juton fabric rather than PAA bleaching. In case of PAA, relatively smaller changes from greige Jute-cotton blend (Juton) fabric were observed in FT-IR spectrum.

SEM micrographs clearly visualized the surface morphologies of greige; PAA and H₂O₂ bleached Jute-cotton blend (Juton) fabric in Fig. 10. PAA and H₂O₂ bleached Jute-cotton blend (Juton) fabric showed clear surface appearance while the surface of greige Jute-cotton blend (Juton) fabric were spotted with impurities. The irregular surface morphology of H₂O₂ bleached Jute-cotton blend (Juton) fabric was observed due to the higher weight loss compared to PAA bleached fabrics as shown in Table 3. Consequently, peracetic acid treated Jute-cotton blend (Juton) fabric performed less weight loss with clean and smooth surface. Thus, the PAA bleaching removed all the impurities with natural colorants without damaging the Jute-cotton blend (Juton) fabric structure.

3.7 Physical changes on bleached Jute-cotton blend (Juton) fabric

Deep coloration and high whiteness values are not only required for bleaching process but also minimum fiber damage is desired. Physical properties of greige, PAA bleached and H₂O₂ bleaching operations were observed that PAA bleached samples revealed highest tensile strength (warp 1820 N, weft 307 N) and elongation (warp 4.4%, weft 34.2%). The enhancement of tensile strength and elongation of the beached fabric compared to the greige fabric can be explained by the increase in the linear density (greige: 2.56 g/km, PAA: 2.62 g/km, H₂O₂: 2.59 g/km) of the yarn due to the shrinkage during wet processing. Therefore, greige Jute-cotton blend (Juton) fabric exhibited lower tensile strength and elongation percentage, because of amorphousness on the fabric surface. Crease recovery properties of
bleached samples were improved for both hydrogen peroxide and peracetic acid bleaching. PAA bleached sample observed high crease recovery angle than greige and H₂O₂ bleached Jute-cotton blend (Juton) fabric. It is clearly summarized that, peracetic acid bleaching agent removed all the impurities on the surface of the fabric. Weight loss (%) of all the investigated samples was presented in Table 3. H₂O₂ bleaching agents not only remove the natural colors and impurities but also it may cause cellulose degradation on to the fabric surface. Hence, the more weight loss (6.4%) was found in H₂O₂ bleached sample.

3.8 Color fastness properties of Jute-cotton blend (Juton) fabrics

Color fastness properties of the dyed Jute-cotton blend (Juton) fabrics which was bleached by using two different bleaching agents (PAA and H₂O₂) was compared in Table 4. PAA bleached Jute-cotton blend (Juton) fabric exhibits better wash fastness and rubbing fastness than H₂O₂ bleached fabrics, probably because of the higher dye uptake (Table 2) of PAA bleached Jute-cotton blend (Juton) fabrics. On the other hand, H₂O₂ bleaching agent causes more cellulose degradation, which influenced less dye uptake on to the surface of the fabric. In case of perspiration fastness, PAA and H₂O₂ bleached Jute-cotton blend (Juton) fabrics showed the identical ratings, 4 to 4.5 for acidic perspiration, and 3.4 to 5 for alkaline perspiration, respectively. The lower rating of color fastness to alkaline perspiration has to do with the low chemical resistance to alkali of the vinylsulphone-based reactive dye used in this study. Light fastness of PAA bleached fabric was higher than that of H₂O₂ bleached fabric and this result can be attributed to the higher dye agglomeration on the surface of the PAA bleached Jute-cotton blend (Juton) fabric because of the higher dye uptake compared to H₂O₂ bleached fabric. Higher dye agglomeration can prevent the photo degradation of dyes due to the lower exposed surface area to light.

3.9 Ecological factors of bleaching bath effluents

The effluents of bleaching bath after bleaching operations was evaluated by biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolve solid (TDS), and dissolve oxygen (DO). Higher BOD, COD values were detected for hydrogen peroxide bleaching compared with PAA bleaching applications shown in Table 5. The effluent of 10 g/L peracetic acid bleaching bath exhibited lower BOD (460 mg O₂/L), COD (1572 mg O₂/L) than same amount of H₂O₂ bleaching bath BOD (631 mg O₂/L), and COD (1572 mg O₂/L). Furthermore, total dissolve solids and dissolve oxygen were represented by PAA bleaching bath shown 1770 mg O₂/L and 9.9 mg O₂/L accordingly. Therefore, it can be explained that peracetic acid bleaching is more environmental

| Sample               | Tensile Strength (N) | Elongation (%) | Crease recovery angle | Weight loss (%) |
|----------------------|----------------------|----------------|-----------------------|-----------------|
|                      | Warp | Weft | Warp | Weft | Warp | Weft | Warp | Weft |
| Greige Juton         | 1435 | 272  | 2.9  | 19.9 | 52  | 44  |      |      |
| PAA bleached         | 1820 | 307  | 4.4  | 34.2 | 72  | 66  | 2.8  |      |
| H₂O₂ bleached        | 1602 | 276  | 4.0  | 27.6 | 65  | 62  | 6.4  |      |

| Sample               | Washing Fastness | Rubbing Fastness | Perspiration Fastness | Light Fastness |
|----------------------|------------------|------------------|-----------------------|----------------|
|                      | SC    | SW   | Dry  | Wet  | SC   | SW   | SC   | SW   | SC   | SW   |
| PAA bleached         | 4     | 4.5  | 4.5  | 3    | 4    | 4.5  | 3    | 4.5  | 4    | 4.5  |
| H₂O₂ bleached        | 3     | 4    | 4    | 3    | 4    | 4    | 3    | 4    | 4    | 4    |

*SC = Staining on cotton, SW = Staining on wool

| Sample     | BOD (mg O₂/L) | COD (mg O₂/L) | TDS (mg O₂/L) | DO (mg O₂/L) |
|------------|---------------|---------------|---------------|--------------|
| PAA bleached | 460           | 1572          | 1770          | 9.9          |
| H₂O₂ bleached | 631           | 2498          | 6430          | 3.6          |
friendly in comparison with hydrogen peroxide bleaching from the ecological point of view.

4. Conclusion

The purpose of this study was to analyze the suitable bleaching agents on Jute-cotton blend (Juton) fabric for deep dyeing. In this work, the optimum bleaching conditions were optimized to enhance the color strength between PAA and H₂O₂ bleaching agents. As a result, it was found that when the Jute-cotton blend (Juton) fabric was dyed using reactive dye, a uniform color strength was obtained for a wide range of bleaching conditions such as bleaching pH, temperature, treatment time and concentrations of bleaching agents. To achieve deep dyeing of Jute-cotton blend (Juton) fabric, the optimum bleaching conditions were found to be as follows: bleaching agent conc. 10 g/L, pH 7 for PAA and pH 9 for H₂O₂, 80°C for 70 min and a material-to-liquor ratio of 1:20. Peracetic acid bleaching agent showed higher dye uptake and fixation than conventional H₂O₂ bleaching. More apparent chemical changes of H₂O₂ bleached fabric demonstrated that hydrogen peroxide bleaching can cause more damages on cellulose and hemicellulose structure of Juton fabric compared to PAA bleaching. Moreover, Peracetic acid bleaching of Jute-cotton blend (Juton) fabric was found to be higher tensile strength and elongation than H₂O₂ bleaching. Peracetic acid bleaching effluent exhibited lower BOD, COD, TDS and higher DO than hydrogen peroxide bleaching effluent. In addition, peracetic acid bleaching provided higher fastness to washing, light and rubbing than hydrogen peroxide bleaching. Although peracetic acid is more expensive than hydrogen peroxide, however for peroxide bleaching catalase enzymes are used for removing the peroxide on the fabric surface. Hence, peracetic acid bleaching eliminates the processing time with enzyme cost. Based on the results, this study demonstrate that the environmentally friendly peracetic acid bleaching can be promising alternatives to the conventional hydrogen peroxide bleaching, as the former can provide high dyeing properties and fastness properties on Jute-cotton blend (Juton) without causing any chemical damages during bleaching process.

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