Influence of Different Alkali on Dyeing Of Cotton with Homo-Bifunctional Reactive Dyes

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Abstract — The study's goals are to ascertain how various alkalis affect cellulosic material and the dyeing process that result. In the presence of different fixing agents, the material was colored using homo-bifunctional reactive dye (high exhaust reactive dye). Sodium carbonate is one of the common alkalis; a comparison with potassium hydroxide and sodium silicate is being conducted. To optimize the dyeing parameters, the conventional recipe's alkali concentration was also adjusted and decreased. The color strength of the dyed cellulose samples was examined in order to ascertain how the various alkalis affected the dyeing procedure. Bright and deep hues are produced by bi-functional reactive dyes because they tend to be highly soluble and have good leveling capabilities. Effluent load and expense were decreased by lowering the alkali concentration, which also produced outstanding shades, equal leveling, and fastness attributes comparable to the conventional recipe.

Keywords: Alkali, Dyeing of Cotton, Homo-Bifunctional Reactive Dyes

I. INTRODUCTION

Since the dawn of modern civilization, cotton has been used as a textile fabric, and a vast variety of garments are made from cotton fibers. Among all the textile fibers, it is the main type of cellulosic fiber. With the formula $(C_6H_{10}O_5)n$, cellulose is an organic molecule that is a polysaccharide made up of a linear chain of several hundred to more than ten thousand β (1→4) connected D-glucose units. Cotton is noted for its comfort, good moisture absorption, and strong wicking qualities. It also has good tensile properties.[1-3]

Reactive dyes are typically used to dye cellulose because of its brightness, range of colors, strong wet fastness, and flexible application. The discovery of bi-functional reactive dyes in the 1970s was a significant breakthrough. Two reactive groups are carried by a dye that is bi-functional. It is possible for the groups to be hetero- or mixed-functional, or homo-bifunctional. The mid-1980s saw a renewed focus on homo-bifunctional types, with additional research being done on items based on bis-vinylsulphonyl and bis-monochlorotriazinyl.[4] Additional benefits of combined bi-functional dyes include enhanced fastness, faster washing-off, and application across a larger temperature range. It is currently offered for sale by over 50 dye makers and is distinguished by its superior economy, high fixation, and variety of application.[4,5] These H-E dyes were designed to considerably outperform comparable products with a single chlorotriazinyl group in terms of fixing and substantivity exhaustion values. A temperature above 80°C was used in conjunction with the thetriazinyl group's propensity for substantivity improvement to promote good fatigue and leveling qualities. This strategy reduced the amount of color in the effluent by improving color use.[6]

Specifically, a significant quantity of electrolyte is needed for the reactive dyes to exhaust. NaCl (common salt) and Na_2SO_4 (Glauber's salt) are the salts that are most frequently used. Additionally, the cellulose fiber surface ionizes in water to produce negative charges, which creates a charge barrier that prevents color molecules from entering. In order to counteract the negative charges on the fiber surface and facilitate the colors' easier diffusion into the fiber, salt is added to the dye bath [7]. Alkali is applied after the dye molecules have been fully exhausted onto the fiber, causing the dye molecules to become fixed on the fiber. The dye bath must remain alkali-free until the dye is fully exhausted in order to prevent the dye from fixing too soon and causing uneven dyeing. Once the dye has been absorbed into the cellulose phase, a reaction between the dye and cellulose may happen.[8,9]

Temperature and alkalinity conditions affect how the reactive site of the dyes interacts with the functional group on the fiber. When alkali is present, reactive dyes react with the cellulosic fiber to create a strong covalent connection between the oxygen atoms of the hydroxyl group in the cellulose and the carbon atoms of the dye molecule. Alkali addition speeds up the rate of neutralization by making the maximum number of -OH groups available in the dye bath. The type of alkali that should be used for fixation depends on type of reactive the dye..[10, 11]

The purpose of the current study was to dye cotton using homo-bifunctional dye, which has higher consistency than hot brand dyes. Additionally, an effort has been made to look at how various alkalies, such as potassium hydroxide, sodium carbonate, and sodium silicate, affect the dyeing of cotton using homo-bifunctional dye. Using accepted evaluation techniques, the findings were assessed for their dyeing performance.

II. MATERIALS AND EXPERIMENTAL METHODS

A. Fibers

There are a number of things to take into account when choosing a cloth for dyeing, such as the fiber composition, weave, and finish (Table 1). The cotton fabric used in this investigation was purchased from local market Vadodara, Gujarat.

Name of fiber	Whiteness index (ASTME313)	GSM (grams per square meter)
Cotton	126.57	110

Table 1: Specifications of fabric

B. Dyestuffs

Reactive dye products belonging to various classes were acquired from a reputable chemical company called Colourtex Ind. Pvt. Ltd. In the current study, homo bifunctional reactive dye with high exhaust was employed (Table 2).

Dye Class	Homo Bi-Functional (High Exhaust) (HE)
Chemical name	C.I. Reactive Blue 172
Commercial name	CoracionNavy Blue HE2R
Reactive Group	Two Monochlorotriazine groups

Table 2: Specification of dyestuff

C. Auxiliaries

Chemical auxiliaries of the Laboratory Reagent (L.R.) grade were employed in this investigation. Table 3 has a report with all the chemical details.

Name of Chemicals	Chemical formula	Molecular weight (g/mol)
Glauber's salt	Na_2SO_4 *$10H_2O$	322.22
Sodium Carbonate	Na_2CO_3	105.98
Sodium meta-Silicate	$(Na_2O)SiO_2$	122.6
Potassium Hydroxide	KOH	56.10

Table 3: Specifications of auxiliaries

D. Experimental Procedure

Prior to dyeing, cotton samples were given a hot wash. The dye bath was prepared for 3% owf (On weight of fabric) shade. The dyeing was carried out in open bath using the exhaust dyeing technique. The cotton fabric sample was dyed at different pH levels using the following procedure, which took into account the varied alkalis employed as fixing agents.

M: L: R	1:30
% Shade	3%
Glaubersalt (gpl)	40
Alkali (gpl)	20, 40, 60
Temperature (ºC)	90-95
Time (mins)	45-60

Table 4: Dye bath formulation for dyeing

Alkali	pH
Sodium carbonate	10.7
Sodium meta-silicate	11.5
Potassium hydroxide	12.7

Table 5: pH of dyebath based on alkali used

All of the samples were dyed using the exhaust dyeing method in a water-heated dyebath in a laboratory. Utilizing HE dyes, a dye bath with a 3% owf shade was created for cotton fabric. After 10 minutes of room temperature dying, the bath's temperature was gradually increased to 95ºC (Table 4). To help the color run out, electrolyte or salt was applied after 15 minutes and left for 30 minutes. The dye bath must remain alkali-free until the dye is fully exhausted in order to prevent the dye from fixing too soon and causing uneven dyeing. As a result, alkali was given to the dye bath after 30 minutes to maintain the pH based on the various alkalis employed (Table 5). After cooling the bath to room temperature and rinsing the samples under tap water, the dyeing process was extended for a further fifteen minutes. The samples were then subjected to a 10- to 15-minute treatment at 60–70 ºC using 2 gpl non-ionic detergents to remove the hydrolyzed unfixed dye from the fiber surface. The samples were then dried after receiving a thorough washing in cold water. A similar process was used to dye cotton using various concentrations of the aforementioned alkalis. After that, the color and fastness characteristics of each sample were examined.

E. Testing and analytical methods

1) Determination of color strength

On various cotton fabric samples, the color parameters of distinct reactive dyed samples were assessed using a computer color matching (CCM) system called the "Premier Color Scan Spectrophotometer" (Model 5100). Different wavelengths of light are transmitted, scattered, and reflected differently by the colored textile materials. The current analysis made advantage of this principle.

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

Where,
K=Absorption Coefficient,
S=Scattering Coefficient
R=Reflectance.

2) Determination of washing fastness (AATCC 61-1994 test method)

AATCC 61-1994 test method was used for the determination of washing fastness of dyed fabrics. Launder-O-meter is used for this purpose. The fabric to be tested of 10 × 4 cm was placed between two adjacent undyed fabrics of same size. Then sewed it along four side to form a composite specimen. The composite specimen was placed in a glass jar containing 5 g/l soap solutionand 2 g/l soda ash solution, keeping material to liquor ratio 1:50. Jars were then closed and placed in Launder-O-meter. Machine was then run for 30 minutes at 60 ± 2ºC temperature after completion of treatment, the samples were removed and washed with water, squeezed, and dried in air. By using Grey scale, the change in shade was assessed and graded from 1 to 5 (1 means poor and 5 means excellent fastness to washing).[12]

3) Determination of rubbing fastness (AATCC-08)

A device used for the rubbing test has a finger of 1-6 cm diameter moving to and fro in a straight line covers a 10 cm track on the specimen with a force of 6N, a suitable apparatus is the crock-meter. The rubbing cloth against which the specimens were tested consist of desized, bleached and unfinished cloth cut into 10x10 cm size. Piece of material to be tested were prepared in two pairs of pieces not less than 15x15 cm^2, one for the dry rubbing and the other for the wet rubbing test. In both the cases, it travels 10 times in 10 seconds along the track. The staining of the rubbing cloth was assessed with grey scale and graded from 1 to 5 (1 means poor and 5 means excellent fastness to rubbing).[12]

4) Determination of light fastness (AATCC 16-B- 1977)

Color fastness to light was evaluated by exposing the dyed samples to sunlight for 8 hours in a normal manner (according to AATCC test method 16-B- 1977) to see the effect of fading of colour due to sunlight. The light fastness properties were evaluated by comparison of exposed portion with the unexposed portion of the material. They were graded from 1 to 8 (1 means poor and 8 means excellent fastness to light) based on blue wool standard scale.[12]

III. RESULT AND DISCUSSION

A. *Effect of different alkali on the color strength (K/S) values of cotton dyed with homo-bifunctional reactive dye*

The laboratory's Premier Color Scan 5100 CCM system was used to measure the dyed samples' color strength. Evaluation was conducted for each sample based on variations in pH and alkali dosage. The results in terms of *K/S* values are presented in Table 6.

Alkali	Concentration of alkali (gpl)	Colour strength (*K/S*)
Sodium Carbonate (Na_2CO_3)	20	1.663
	40	1.671
	60	2.072
Sodiummeta-Silicate [$(Na_2O)SiO_2$]	20	1.101
	40	1.466
	60	2.43
Potassium Hydroxide (KOH)	20	1.293
	40	1.46
	60	1.624

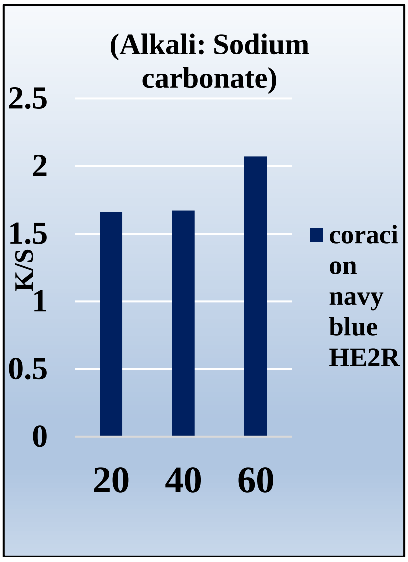
Table 6: Colour strength (*K/S*) values of cotton sample dyed with homo-bifunctional reactive dye

1) *Effect of alkali*

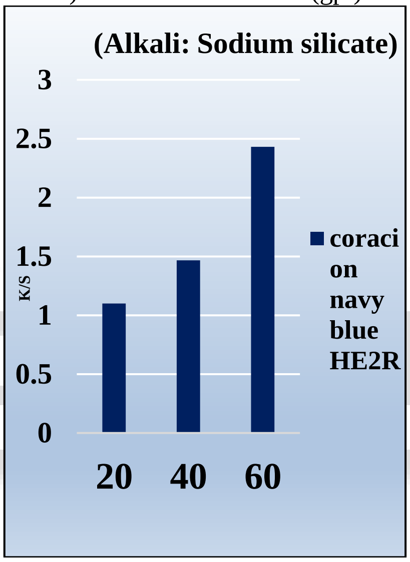
Various alkalis were employed as fixing agents in cotton dyeing, as this study examines. It was for this reason that the pH varied according to the alkalis employed. While potassium hydroxide and sodium meta-silicate provide a greater alkaline environment for dyeing, HE dyes need a milder alkaline environment to create covalent bonds. Although these two alkalis can be employed as a buffer system, they provide duller colors when used alone since HE dyes cannot withstand extremely high alkaline dyeing conditions [13]. Because soda ash is a moderate alkali and is in the right pH range, it reacts with the fiber to create a long-lasting bond that keeps the dye attached to the fiber. In all three of the dyebath's alkali concentrations, it effectively activates the fiber molecules to allow them to chemically attack the dye and provide outstanding depth of shade (Figure 1).

2) *Effect of concentration of various alkalis*

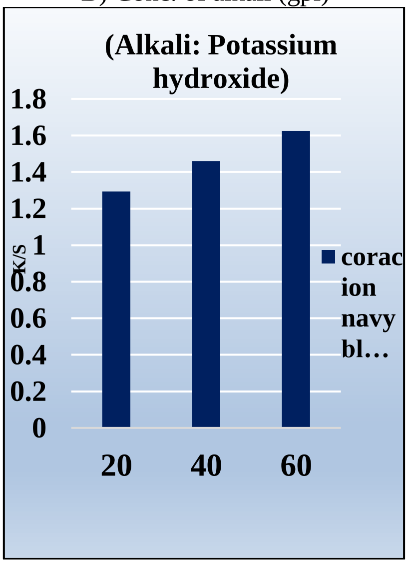
The dyeing recipe took into account three distinct alkali concentrations. As needed, the normal concentration of 40 gpl produced the best outcomes. When the concentrations were changed, the findings demonstrated that the depth of shade was achieved at or nearly as well as that of samples dyed in the presence of 40 gpl of alkali when the concentration was reduced, i.e., 20 gpl. Additionally, as the alkali effluent load rises, greater alkali dosages, such as 60 gpl, are found to be environmentally hazardous.



A) Conc. of alkali (gpl)



B) Conc. of alkali (gpl)



C) Conc. of alkali (gpl)

Fig. 1: Color strength obtained based on different alkalis used i.e., (a) Sodium carbonate, (b)Sodium meta-silicate, (c) Potassium hydroxide

B. Effect of different alkali on the fastness properties of cotton dyed with homo-bifunctional reactive dye

The fastness attributes are the most crucial requirements for any dyeing from the perspective of the consumer. Table 7 displays the results of the evaluation of the dyed samples' fastness properties. When dyed with varying alkali dosages, the homo bifunctional reactive dye utilized in this work was seen to have very good to exceptional fastness to washing, rubbing, and light. This is because reactive dye exhibits good fixation on cotton at any concentration by forming a covalent bond with the cellulose fibers in the presence of alkali.

Name of alkali	Concentration of alkali	Washing fastness ratings (1 to 5) (colour stain)		Rubbing fastness ratings (1 to 5)		Light fastness ratings (1 to 8)
		Dry rubbing	Wet rubbing	Colour stain	Colour change	Colour fading
Sodium Carbonate (Na_2CO_3)	20	5	5	5	5	7
	40	5	5	5	5	7
	60	5	5	5	5	7
Sodiummeta-Silicate [$(Na_2O)SiO_2$]	20	5	5	4.5	4.5	5
	40	3.5	4.5	3.5	4.5	7
	60	4	3.5	4	4	7
PotassiumHydroxide (KOH)	20	3.5	3.5	4	4	5
	40	4.5	3.5	4.5	3.5	5
	60	4	4	3.5	4	7

Table 7: Fastness ratings of cotton dyed with homo-bifunctional reactive dye

IV. CONCLUSION

Brighter hues and better exhaustion are produced when homo-bifunctional dyes are applied to cotton fabric. According to the study's findings, sodium carbonate produced a superior fixation than other alkalis when utilized as a fixation agent. This was because sodium carbonate supplied the ideal pH level needed for HE dyes. When the amount of alkalis was varied, it was discovered that dropping the concentration below the recommended level might produce great results. Because potassium hydroxide and sodium meta-silicate are extremely alkaline by nature, they negatively affect the dye's pH and higher concentrations of these alkalis can result in higher effluent loads. As a result, it can be said that sodium carbonate, when employed under conditions of lower concentration, can produce equally good outcomes as regular alkali dosage while also reducing effluent burden.

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