Indian Journal of Fibre & Textile Research
Vol. 41, June 2016, pp. 217-220

Electrochemical bleaching of cotton

Dipankar Das, A K Patra[a], Rahul Jakhar & Shyam Sunder

Department of Textile Chemistry, The Technological Institute of Textile & Sciences, Bhiwani 127 021, India

Received 10 April 2014; reviesd received and accepted 19 September 2014

An attempt has been made to compare the effect of electrochemical bleaching with conventional bleaching of cotton. Electric current is used in the preparation of a bleaching agent to replace bleaching powder. The NaOCl generated from electrolytic cell (2.5-3.5V potential difference) is sufficient to produce powerful bleaching agent with available chlorine varying from 1.2 g/L to 1.3g/L. Time required for bleaching reduces to 10-20 min, as compared to 90 min in conventional bleaching. Whiteness index, brightness index and yellowness index have been measured by a spectrophotometer. There is a remarkable increase in whiteness index and brightness index and decrease in yellowness index in the electrochemically bleached samples as compared to that in conventionally bleached cotton. Dye uptake values show an increasing trend with electrochemical bleaching. The present study aims for achieving the desired efficiency to remove conventional drawbacks of sodium hypochlorite bleaching.

Keywords: Brightness index, Electrochemical bleaching, Sodium hypochlorite, Whiteness index, Yellowness index

Bleaching is a process by which natural colouring matter and any other colouring matter is removed from natural fibres or a process decolourisation from man-made fibres[1]. If the fibre brightness is not important, no bleaching is required. However, for light and medium shades or when fibre fineness is important, bleaching becomes an essential operation before dyeing and printing. The natural colouring matter can be destroyed by oxidation or by reduction or as a combination of both[2]. Oxidative bleaching is preferred over reductive bleaching because whiteness produced by a reducing agent is not permanent[3]. Out of all the bleaching agents, bleaching with sodium hypochlorite or hydrogen peroxide is widely used. Now a days, the problem associated with sodium hypochlorite bleaching is encouraging the industrialist to opt for hydrogen peroxide bleaching[4]. But electrochemically, NaOCl can be generated and used as a bleaching agent without transportation or storage of hypochlorite liquor. In this study, sodium hypochlorite has been generated *in situ* with a simple electrolytic cell having a potential difference inside the cell of 2.5-3V and the effect of electrochemical bleaching is compared with conventional bleaching of cotton. There is also no effluent problem associated with electrochemical bleaching. It is also advantageous in the respect of economy, reliability, cleanliness and convenience in working.

[a]Coresponding author.
E-mail: arunkpatra@rediffmail.com

Experimental

Plain weaved grey cotton fabric was used for the study. Spectrophotometer (Model: SS5100A, Make: Premier Colorscan) was used. Sodium chloride: (AR grade), obtained from S D Fine Chem. Limited, Mumbai, was utilized as bleaching material. The electrolytic cell parameters are given in Table 1.

The electrolytic cell is charged with 30g/L salt solution and fitted with two carbon plate electrodes, the anode being covered with red calico. In the electrolytic decomposition of sodium chloride salt the chloride is separated into its constituent elements, sodium and chlorine, the former combining with

Table 1—Specifications of raw materials used in electrolytic cell[5-7]

Parameter	Value
Cathode material	
Geometric area	71.5 cm^2 (11*6.5cm)
Number of cathode	2
Material	Graphite(Carbon)
Length	11 cm
Anode material	
Geometric area	71.5 cm^2 (11*6.5cm)
Number of anode	2
Material	Graphite(Carbon)
Length	11cm
Inter electrode spacing	15cm
Anode to cathode surface area ratio	1:1
Catholyte	
Composition	Brine solution
Volume	3L
Anolyte	
Composition	Brine solution
Volume	3L
Cell current arrangement	
Total current	1-10A
Current density	0.5-5 A/m^2
Cell voltage	2.5-3V

water to form sodium hydroxide and hydrogen. Simultaneous presence of chlorine and sodium hydroxide give NaOCl. In the electrolytic cell the following reaction takes place[1]:

$$2Na^+(aq) + Cl_2(g) + 2OH^-(aq) \rightarrow NaOCl(aq) + NaCl(aq) + H_2O$$

The grey cotton fabric was desized to remove the sizing material and efficiency of desizing was checked by Tegewa scale. Desizing was carried out in a winch followed by scouring by treating the desized fabric with NaOH. The efficiency of scouring was checked by weight loss method and by absorbency test. This process renders the fabric in a more absorbent state. Recipes for these are mentioned below:

Desizing		
MLR	:	1:30
Enzyme (Bactosol HTN)	:	1%owf
NaCl	:	5%
*p*H	:	5.5-6.5
Temperature	:	80^0 C
Time	:	1 h
Scouring		
MLR	:	1:30
NaOH	:	4%
Na_2CO_3	:	2%
Wetting agent	:	1%
Temperature	:	At boil
Time	:	2 h

Part of the fabric samples was bleached conventionally[8] and remaining part was electrochemically bleached.

In electrochemical bleaching, 5 g scoured fabric samples were taken and after attainment of 0.6915 g/L of available chlorine the fabric was put into the electrochemically prepared solution for bleaching. This much amount of available chlorine was found sufficient to get a good bleached fabric.The process of bleaching was continued for 20 min and after that the sample was cold washed 2 times for 5 min and hot washed once. Then the sample was dried and weighted, the weight was found to be 4.96 g. The efficiency of bleaching was checked by calculating the whiteness Index through the spectrophotometer. Then the samples of conventional and electrochemical bleaching were dyed with different dyes to check their effect on the sample. Samples were dyed with 3 different dyes, namely Cibacron Yellow FN-2R, Cibacron Red H-FN-8B and Cibacron Orange HR. The recipes for the above processes are given below[8]:

Conventional bleaching		
MLR	:	1:30
NaOCl	:	3 g/L
Na_2CO_3	:	To maintain *p*H
*p*H	:	10.5-11
Time	:	1.5 h
Reactive dyeing		
MLR	:	1:30
Shade	:	0.5%
NaCl	:	40 g/L
Na_2CO_3	:	8 g/L
*p*H	:	9-10

Results and Discussion

The whole study is divided into two parts, namely (i) preliminary study intended to determine the optimum conditions for electrolysis, and (ii) comparative study between electrochemical and conventional bleaching process.

In the preliminary study, electrolysis has been carried out by varying the concentration of the solution (10,25,50,70 and 100 g/L) iodometric titrations have been carried out using KI, $Na_2S_2O_3$, glacial acetic acid and starch as reagents. Available chlorine is calculated after 70min by using the following formula[6,7]:

$$\% \text{ Active chlorine} = [3.545 * N * V] / Y$$

where V is the volume of 0.1 N $Na_2S_2O_3$ consumed; Y, the volume of the sample taken; and N, the normality of KI solution[4]. The available chlorine obtained is found to be 0.1615, 0.3417, 0.6915, 0.7325 and 0.7512g/L for 10, 25, 50, 70 and 100 g/L salt. Also, the available chlorine obtained in the cell after 70, 80, 90,100,110 min from starting is found to be 0.6915, 0.7225, 0.7667, 0.7894 and 0.7924 respectively. It is found that as the concentration of the salt solution increases, the available chlorine increases but very high concentrations cannot be used because this may damage the substrate and also reduce the ion mobility. On the other hand, very less concentrations do not give the desired results. Hence, salt concentration of 40-50 g/L gives the desired results; 1-1.5 g/L of available chlorine can be produced if the apparatus is kept closed.

The conventional and electrochemically bleached samples are evaluated on a spectrophotometer.

Their relative whiteness, yellowness and brightness indices are found to be 82.409,16.641 & 61.946 for conventional bleaching; and 86.682,12.671 & 70.274 for electrochemical bleaching respectively.

From the analysis it can be easily observed that brightness and whiteness indices of electrochemically bleached samples show higher values than conventionally bleached samples under similar conditions. Yellowness index of conventionally bleached samples is found to be higher than that of electrochemically bleached samples. CIE Lab values of electrochemical and conventional dyed samples given in Table 2.

Electrochemically bleached-dyed samples are compared with the conventionally bleached-dyed samples in (Fig. 1).

CIE Lab and *K/S* values are coordinated for all the dyed samples. Results show that the colour depth and shade for the same dye concentration are comparable for the two types of bleaching. It is also observed that in the electrochemical bleaching it takes hardly 10-20 min to bleach the sample after attainment of the required concentration of available chlorine, whereas in conventional bleaching it takes around 90 min to bleach a sample properly. Thus, there is a large saving of time. As compared to the conventional bleaching, electrochemical bleaching is economically more viable. This can be justified by the following points:

(i) Water consumption is less as compared to the conventional bleaching.
(ii) Electrodes used for the setup have long life and the setup of the cell is cheap.
(iii) Only 2–2.5V of electricity is needed to produce the NaOCl, so there is less consumption of electricity.
(iv) Setup of the cell is simple, so the maintenance cost is also less.

It is concluded that the industrial feasibility of a process needs various considerations. It must fulfil various protocols and industry requirements and must comply with the stringiest environmental rules. These factors have been studied in a pilot scale. Optimized conditions have been sought and the following conclusions are drawn from the study

(i) Material saving—Chemicals consumption is very less. Only AR grade salt and water can produce the required NaOCl. The electrodes used are also cheap and have long life. Maintenance cost is also very less.
(ii) Better whiteness index—It is observed that the average WI of the electrochemically bleached samples is greater than that of the conventionally bleached, scoured and grey samples. The average YI of the electrochemically bleached samples is less and they have higher BI than the other samples.
(iii) Process reliability—The *in situ* manufacturing of NaOCl is highly reliable because this need not depend on the suppliers for the chemical. Sudden increase in the cost of the chemicals will not affect the process house.

Table 2— L^*,a^*,b^* values of the samples

Name	L^*	a^*	b^*
Electrochemical			
E1(yellow)	82.289	9.907	84.661
E2(orange)	51.253	54.391	35.052
E3(red)	35.065	46.583	25.482
Conventional			
C1(yellow)	81.968	9.809	84.792
C2(orange)	50.569	54.303	35.098
C3(red)	34.872	45.658	24.836

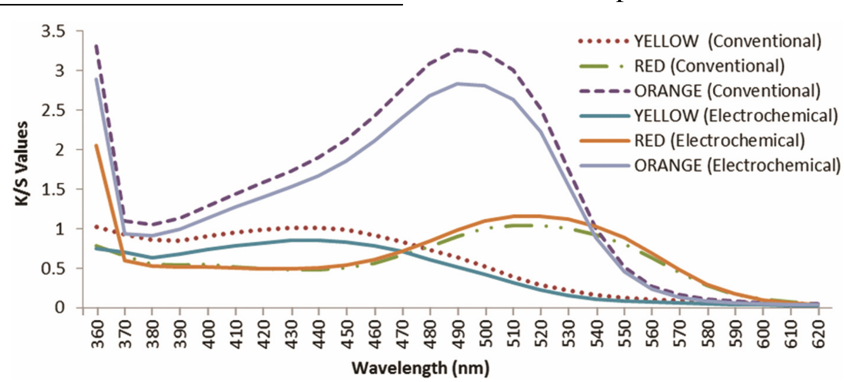

Fig 1—Comparison of colour strength (*K/S*) on dyeing for conventionally and electrochemically bleached samples.

(iv) Shorter time—In conventional bleaching, it takes around 90 min to bleach a sample properly[8], but in the electrochemical bleaching it takes hardly 10-20 min to bleach the sample after attainment of the required concentration of available chlorine. Thus, there is a large saving of time.

(v) Clean process—The electrochemical bleaching is clean and thus the working in this environment can be more pleasant for the persons.

(vi) Ecofriendly—Electrochemical bleaching is ecofriendly because there is no production of water polluting chemicals. Thus, there is no effluent problem.

These results offer new prospects for the electrochemical bleaching. This innovative electrochemical bleaching of cotton can usher a new era in textile processing industry with further applications and markets to be explored.

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