Green technology in textile processing: Part II — Bleaching of polyester/cotton fabric

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Two new formulations have been prepared for bleaching of polyester/cotton (48:52) dhoti fabrics and the results of bleaching with these formulations have been compared with those of the conventional process. The new formulations result in significant savings in steam, electricity and water. A total saving of 10.67% in the cost of polyester/cotton dhoti preparation has been reported. These formulations are also eco-friendly as they avoid use of toxic bleaching agents, require lesser concentration of chemicals and generate reduced load of effluent. Biological oxygen demand and chemical oxygen demand lower by 38% and 35% respectively have been reported.

Keywords: Bleaching, Eco-formulations, Eco-processes, Polyester/cotton dhoti

1 Introduction
The chemical processing of textile consumes large quantities of water. Consumption of water varies from fibre to fibre and the quantities of pollutants that form the pollution load going into waste water depending on a particular chemical process followed. Synthetic fibres contain spin-finishes, coning oils, sizes and adventitious dirt as impurities. A mild scouring treatment removes these impurities. Although the bleaching of polyester component is not required in the case of fabric to be dyed later, it is essential to obtain pure white goods since the polyester fibres get discoloured during heat treatment. This is particularly true in case of polyester/cotton dhotis, which have become very popular in rural and semi-urban areas of our country.

Cotton dhoti, in general, and polyester/cotton dhoti, in particular, are very popular as the traditional dress in rural and semi-urban areas in India and in some countries in Asia and Africa. Polyester/cotton blend fabrics are normally bleached with sodium hypochlorite, followed by sodium chlorite and hydrogen peroxide. Though sodium hypochlorite imparts whiteness to cotton component, it does not produce good white polyester component of the blend. Further, sodium hypochlorite is not eco-friendly due to its chlorite content. With hydrogen peroxide also, polyester does not get bleached satisfactorily. Sodium chlorite, however, has a bleaching action on polyester as well as cotton. While most other bleaching agents produce only an ivory white on synthetic fibre fabric, sodium chlorite renders the fabric a pure intrinsic chalk white. But sodium chlorite under acidic conditions is extremely corrosive to plant and equipment and the addition of sodium nitrate to prevent corrosion leads to pollution of water. The chlorine dioxide fumes evolved during bleaching are very toxic. Various chemicals and their mixtures to protect the stainless steel from attack by sodium chlorite or chlorous acid have been reported. Butcher reported the use of fluorescent whitening agents in place of hazardous sodium chlorite. Recent developments like use of various eco-friendly enzymes in desizing and scouring have been reported. Besides these, some noteworthy work in the development of polymeric dispersants like sugar polymer based cleansing agent has been reported.

In the present work, two formulations have been prepared which are aimed at avoiding toxic/banned chemicals, reducing the concentration of chemicals and thereby reducing waste concentration, reusing the wash water containing low pollution loads and reducing steam and electricity consumption during bleaching of polyester/cotton (48:52) dhoti fabric.
The chlorine-based bleaching agents have been replaced by chlorine-free bleaching system based on acidified potassium permanganate solutions.

2 Materials and Methods

2.1 Materials

Polyester/cotton (48:52) dhoti fabric having the following specifications was used: warp count, 60s; weft count, 80s; ends/in, 80; and picks/in, 80.

Sulphuric acid, hydrochloric acid, calcium chloride, magnesium sulphate, ferric chloride, mercuric sulphate, silver sulphate, potassium dichromate, ferrous ammonium sulphate, all of AnalaR grade, were used. The non-cresylic wetting agent Mercein NC (M/s Ahura Chemicals, Mumbai) was used.

2.2 Methods

2.2.1 Desizing

Separate desizing step has been eliminated in conventional method and in formulations I and II as the size consists of water soluble materials such as polyvinyl alcohol and modified starches.

2.2.2 Bleaching

Conventional Method

The polyester/cotton dhoti fabric was grey mercerised with a solution containing 44° Tw (245 g/l) sodium hydroxide and 0.25% non-cresylic wetting agent for one min at 30°C followed by hot and cold wash with water. Scouring was then carried out using 2% (owf) sodium carbonate and 0.25% (owf) non-ionic detergent at 70°C for 2 h. The scoured fabric after hot and cold wash was subjected to chemicking with sodium hypochlorite (3.0 g/l available chlorine) for 2 h followed by washing. The bleaching was carried out with 5.0 g/l sodium chlorite, 2.0 g/l sodium nitrate and 2.0 g/l formic acid (85%) at boil for 3 h followed by two washing treatments. The fabric was then subjected to peroxide bleaching with 0.28% (owf) hydrogen peroxide (50%), 0.4% (owf) sodium silicate, 0.2% (owf) sodium hydroxide and 0.11% (owf) wetting agent at 85°C for 3 h. The fabric was finally washed twice before drying.

Formulation I

The grey fabric was hot mercerised with a solution containing 35° Tw (182 g/l) sodium hydroxide and 0.125% non-cresylic wetting agent at 70°C for 45 s followed by hot and cold wash with water.

The fabric was subjected to bleaching with 0.3% (owf) potassium permanganate, 98% sulphuric acid (1/4th part of permanganate) and glacial acetic acid (3/4th part of permanganate) at 60°C for 30 min followed by washing. The fabric was then treated with 4.0 g/l oxalic acid at 85°C for 30 min and washed. Finally, peroxide bleaching was carried out with 0.2% (owf) hydrogen peroxide (50%), 0.2% (owf) stabilizer AWNI, 0.2% (owf) sodium hydroxide and 0.1% (owf) detergent at 85°C for 3 h. The fabric was finally subjected to hot wash and cold wash with water before drying.

Formulation II

The processing sequence was same as for formulation I. However, potassium permanganate and hydrogen peroxide leftover from formulation I were put to reuse after replenishment. The replenishment of permanganate bleaching bath was done with 0.18% (owf) potassium permanganate and that of peroxide bleaching bath with 0.15% (owf) hydrogen peroxide (50%), 0.15% (owf) stabiliser AWNI, 0.1% (owf) sodium hydroxide and 0.05% (owf) detergent.

The wash liquor obtained in the cold washing of hot mercerised fabric in formulation I was put to reuse in formulation II for hot wash after mercerisation. Similarly, the wash liquor obtained in washing of permanganate-treated fabric in formulation I was reused for washing of permanganate-treated fabric in formulation II. The wash water obtained from the second wash after peroxide bleaching in formulation I was reused for first wash after peroxide bleaching in formulation II.

2.2.3 Tests

Suspended solids, total dissolved solids, biochemical oxygen demand (BOD), chemical oxygen demand (COD), pH, tensile strength, whiteness, yellowness, whiteness retention, copper number and carboxyl values were determined as reported earlier.

3 Results and Discussion

The waste water generated in the various stages of pretreatment of polyester/cotton (48:52) dhoti fabric was analysed for pH, total solids, total dissolved solids, suspended solids, BOD and COD and the results are given in Table 1. Bleaching of polyester/cotton (48:52) dhoti fabric generates less volume of effluent and the pollution load is also lower as compared to that in bleaching of cotton fabrics. However, in the conventional method,
rather large quantity of water is consumed generating higher pollution load. To curtail water consumption and reduce pollution load, formulations I and II were prepared. The hot mercerisation treatment with mild alkali and detergent at 70°C serves the purpose of desizing, scouring and mercerising in a single operation in formulations I and II, thereby shortening the processing sequence. The mercerising effluent from formulations I and II have higher total solids, total dissolved solids, suspended solids, BOD and COD as compared to that for the effluent from the conventional mercerising method. This may be due to the removal of significant quantities of both natural and added impurities in hot mercerisation. However, the effluent generated in hot mercerisation is much smaller in volume as compared to the scouring effluent of conventional method.

The total BOD for the formulation I is 640 mg/l comprising 60 mg/l in bleaching and 580 mg/l in mercerising as compared to 1028 mg/l for the conventional method which comprises 880 mg/l in scouring, 92 mg/l in bleaching and 56 mg/l in mercerising. Similarly, the COD value for the formulation I is 1816 mg/l as compared to 2797 mg/l for the conventional method. Thus, reduction in the BOD and COD values is by about 38% and 35% respectively.

To take care of the absorbable organohalogens (AOX) problem, sodium hypochlorite bleaching and sodium chlorite bleaching, generally followed in the conventional method, were phased out in formulations I and II and instead eco-friendly potassium permanganate bleaching was adopted. The permanganate bleaching effluent (formulations I and II) showed lower values of total solids, total dissolved solids, suspended solids, BOD and COD as compared to that by the effluent of the conventional method. It may be seen from Table I that the overall pollution load is maximum for conventional method followed by formulation II and formulation I.

Table 2 shows the results of the physical and chemical analysis of polyester/cotton (48:52) dhoti fabric. The whiteness values and Yellowness index
values obtained with formulations I and II are comparable to those obtained by the conventional method. Slightly lower values of copper number, carboxyl content and loss in tensile strength for samples bleached with formulations I and II indicate that no additional damage has been done in formulations I and II as compared to conventional bleaching.

Table 3 shows the projected savings in steam, electricity and water on bleaching polyester/cotton (48:52) dhoti fabric in a process house with formulations I and II instead of conventional method. The savings are based on the assumptions given in Appendix I. It is observed that the formulation I results in savings of 3000 kg steam, 73.78 kWh electricity and 40,000 litres of water per day, whereas the formulation II results in savings of 3000 kg steam, 73.78 kWh electricity and 56,000 litres of water. The cost of bleaching polyester/cotton dhoti by the conventional method is Rs 10.50 per kg. The data show that with formulations I and II there is a saving of Rs 1.12 per kg in a process house. Thus, there is a total saving of 10.67% in the cost of polyester/cotton (48:52) dhoti fabric preparation.

References

Appendix I—Steam, electricity and water required for processing 4000 m (approx. 2000 kg) of polyester/cotton dhoti fabric at shop floor level
Steam consumption for scouring=1 kg/kg of fabric
Steam consumption for peroxide boil=1 kg/kg of fabric
Steam consumption for formulation bleaching (permanganate bleaching)=0.5 kg / kg of fabric
Steam consumption for sodium chlorite bleaching=0.5 kg / kg of fabric
Rating of kier circulation pump=5 HP (3.75 kW)
Motor of washing machine=5 HP (3.75 kW)
Average production of washing machine=100 m/min
Water requirement for washing after scouring=16 litres/kg of fabric
Water requirement for washing after bleaching=9 litres/kg of fabric
Cost of steam=Rs 0.60/kg
Cost of electricity=Rs 3 / kWh
Cost of water=Rs 55 per 10,000 litres