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Short Communication

A Step towards Environmental Protection in Textile Wet Processing

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Abstract

Environmental awareness is the most often talked subject in today's industrial and social scene all over the world. In India, right now the quantum of problem associated with the effluent by industrial waste is small but with rapid industrialization, increases rapidly to a significant level. Chemical processing of textile material is one of the leading consumers of water (50 to 300 liters of water per kg of textile material) and the second biggest effluent generating industry. Among the various wet processing steps, pretreatment process, utilize the highest amount of water. Many approaches, namely, development of machines/techniques to reduce liquor consumption, application of green chemicals, biotechnology applications, quality control and inventory management, and others have been made to minimize water/effluent minimization. In the present research, the two important steps in pretreatment process, namely mercerization of cotton and scouring of synthetic fibers have been centralized through water consumption to minimize effluent loads. Both these processes have been performed in the present work through the application of solvents (no water used). After the said pretreatment processes more than 90% of solvent can be recovered and recycled for next processes. The new innovative processes were compared with the conventional processes. The results obtained are quite comparable to that of conventional process and encouraging. In future commercialization of these processes will be tried.

Keywords: Environment, pretreatment, solvent, textiles, wet processing.

Introduction

Next to leather, textile industries are leading consumer of water. Cotton fibres required the highest (appx 250 – 350 Kg / Kg of fabric) and synthetic fibres the lowest (appx 100 – 200 Kg / Kg of fabric) amount of water. The water consumed in processing department is about three times than all the other units put together and bleaching process, the highest consumer (table1)[1-3]. The conventional preparatory processes of textiles namely, desizing, scouring, bleaching and washing are highly water and energy consuming operations (table–2)[4].

Table–1
Water consumption in textiles units

Process	Water consumption (%) of total
Bleaching and finishing	38
Dyeing	16
Prrinting	8
Boiler	14
Humidification (spnning and weaving)	15
Sanitary and others	9

Various approaches have been developed in textile processing to minimize water consumption[5-7]. Development of machineries having low liquor ratio. Conversion of batch-wise process into semi-continuous/continuous process. Development of chemicals / auxiliaries to improve process efficiency. Application of solvent in pretreatment & other processes. Development in washing mechanism such as counter current washing, aquatex washing, powerful jets, vibrator washing etc. Reuse and recycle of process chemicals / liquor. Many researchers have worked on the said principles to minimise water usage (and energy usage) in pretreatment process. However, very few literatures were available pertaining to use of solvent technology in pretreatment and mostly all in scattered manner [8-14, 16]. In the present research, two important operations of pretreatment namely, mercerisation of cotton and scouring of synthetic fibres have been performed by using the solvent (No water). The efficiency of solvent processes have been compared with that of conventional processes. Further, solvents have been recovered and reused in next operations and result were analyzed.

Table–2
Consumption of water and energy in pretreatment process

Process	Consumption of water (Kg / Kg of Fabric)	Consumption of steam (Kg / Kg of Fabric)
Desaizing	3	0.25
Washing	20	0.35
Couring	2	1.75
Washing	20	0.30
Bleaching	2	1.00
Washing	40	0.60
Total	87	4.20

Material and Methods

The plain woven cotton, polyester and nylon fabrics were procured from local textile unit and used throughout the experiments (table–3). All the chemicals used in present investigation were of laboratory reagent grade. The details of two solvents used in present study have been reported in table.

Table–3
Specifications of fabrics used

Fibre/Specifications	Cotton	Polyester	Nylon
Wt (gm) / mt^2	125	106	111
EPI	103	66	74
RPI	100	57	66
Stage	After bleaching	Grey	Grey

Table–4
Specifications of solvents used

Solvent / Specifications	Ammonia	Trichloroethylene
Chemical formula	NH_3	$ClCH=CCl_2$
Molecular weight	17	130.5
Boiling Point (^oC)	- 33.4	86.9
Specific gravity (g/cc)	0.817	1.464

Mercerization of cotton: Cotton fabric was conventionally mercerised on laboratory model chain mercerising machine. The fabric was padded in sodium hydroxide solution (48 – 52^o Tw) at room temperature and given dwell time of 45 seconds with warp tension. In the solvent mercerisation process, cotton fabric was passed through liquid ammonia solution and aged for 45 – 60 seconds with warp tension. In both the processes after mercerisation fabric was washed thoroughly to neutral pH with distilled water. In solvent process, after mercerisation ammonia was recovered and recycled for next operation.

Scouring of synthetic fibres: Polyester and nylon fabrics were scoured conventionally using non ionic detergent (1 % w/v) at 90^oC for 30 minutes. In the solvent scouring process, polyester and nylon fabrics were treated in solvent (trichloroethylene) at 50^oC for 10 minutes. After completion of scouring, solvent was recovered by distillation process and reused. After scouring, in both the operations, fabric was washed to neutral pH with distilled water.

Analytical procedures: Weight loss percentage of treated samples were determined by finding the differences in weight of sample before and after treatment and always after conditioning. Wettability of sample was determined by standard prescribed drop test method. Moisture content, tensile strength and dye exhaustion of various samples were determined as per the process prescribed earlier [15]. Swelling of fibre, cross-section and uniformity of reactions were analysed microscopically. Luster and feel of various samples were evaluated by subjective test method.

Results and Discussion

Mercerization of cotton using ammonia: Cotton fabric was mercerized using liquor ammonia (solvent) and compared with conventional caustic soda process. The efficiency of mercerisation waas determined in terms various parameters namely, swelling, cross section, lustre, moisture content, dyeability etc and results obtained are reported in table–5.

Ammonia is a powerful and rapid swelling agent for cellulosic fibres and reacting mainly on ordered region. The swelling reaction in liquid ammonia proceeds at considerably faster rate than in conventional caustic soda treatment. Further, the recycled ammonia has also comparatively faster rate of swelling than conventional process. Liquid ammonia treatment results in a smooth and more uniform fibre surface compared to caustic soda treatment because of the less compressive strains and frictional force in former one. Cotton fabrics treated by liquid ammonia process improved the tensile properties, luster, appearance and wrinkle recovery of the materials. Liquid ammonia causes swelling of cellulose and can be completed recycled. Because of the cyclic nature of this process, there would be no pollution, while conventional mercerising using caustic soda creates problems of pollution. Moisture absorption capacity is related with the porosity of structure.

Table–5
Properties of mercerized cotton after conventional and liquor ammonia processes

Property	Caustic treated	Ammonia treated	Recycled and treated
Swelling	Slower and less	Faster and high	Medium
Cross section	Round and lower thickness of cell wall	Round and increase in thickness of cell wall	Round and higher convoluated
Uniformity	Poor	Better	Medium
Luster	Superior	Medium	Lower
Moisture content (%)[a]	5.71	5.84	5.74
Dye exhaustion (%)[b]	153	144	139
Tensile strength (kg/cm)[c]	4.11	4.19	4.16

Values of untreated fibre a : Moisture content = 5.61 %, b : Dye exhaustion = 100 %, c : Tensile strength = 3.84 kg/cm

Higher moisture content on liquor ammonia mercerization indicates increase in porosity of structure. Comparative dyeing tests on unmercerized, caustic mercerized and ammonia mercerized cotton samples indicated that caustic mercerization greatly enhanced dye substantivity compared to ammonia treatment. This may be because the swelling occurs with ammonia is mainly in the ordered region while in case of caustic soda in both the regions i.e. ordered and disordered and dye molecules do not enter in ordered structure. Compared to untreated sample, the liquor ammonia treated sample appears rounder but lesser than the conventional treated sample. The uniformity of fibrillar structure is better in case of ammonia compared to caustic soda resulting in improvement of tensile strength in higher values. This can be explain as : Liquid ammonia process is both 'Inter fibrilar' and 'Intra fibrilar'. The differences between caustic soda and liquid ammonia, is in the size of penetrating molecules. Ammonia molecules are smaller in size penetrates better in the cellulosic structure and also cross links with the parent molecules. However, the boiling point of liquid ammonia is -33^{o}C and therefore the said process is very difficult to operate. This is to be handled very carefully and recycled effectively.

Solvent scouring of synthetic fibres: Scouring of the most commonly used synthetic fabrics (polyester and nylon) are carried out using solvent and conventional methods. The efficiency of scouring was evaluated in terms of weight loss percentage; wettability, strength loss etc. are reported in table–6. It has been found that (table–6) weight loss percentage is slightly higher on both the fibres with solvent in comparison to conventional process. Further, wettability and dyeability values are also improved in solvent scoured samples. This may be due to the removal of all the impurities by high penetrating action of solvent. No oligomers in polyester have been observed on solvent scoured sample and feel of fabrics also improved. However, tensile strength reduced to higher extent in case of solvent scouring process in comparison to conventional process.

Important significance of solvent scouring for synthetic fibres can summarized as : Feel of the fabric appears fuller. Complete removal of oligomers from polyester fibre. Lower cost of process (as solvent can be recycled). Better dyeability and wetability. Minimum damage to the material. Reduced water pollution. Solvents used in textile processing are inexpensive, readily available, non-toxic, non-flammable, stable to repeated recovery, inert to textiles and non-corrosive. The main difficulties of solvent scouring are the need for systems to recover from fabric after processing. However, the growing problems associated with the increasing demand for raw water and discharge of effluent have given an impetus to the solvent based processing systems.

Conclusion

Development of solvent based processing techniques of textiles, have gained much popularity in view of the water shortage in all parts of world. Two important steps of pretreatment i.e. mercerization of cotton and scouring of synthetic fibres, which consume lots of water and toxic chemicals have been examined by solvent treatment. It has been safely said that both the processes can be satisfactorily carried out with the solvents. The outputs of laboratory results are quite compatible to the conventional process. Liquor ammonia is the best alternative for caustic mercerization for cotton and chlorinated solvents to the conventional scouring for synthetic fibres.

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Table – 6
Scouring of PET and Nylon using solvent and conventional process

Properties	Polyester			Nylon		
	Grey	Solvent treated	Conventional treated	Grey	Solvent treated	Conventional treated
Weight loss (%)	-	4.13	3.71	-	4.28	3.76
Absorbency (Sc)	>180	4	6	> 180	3	6
Dye exhaustion (%)	100	140	128	100	151	136
Feel	Harsh	Fuller	Medium	Harsh	Better	Medium
Cost (per/kg)	-	X	1.8 X	-	X	2.1 X
Oligomers	High	No	Medium	-	-	-
Strength (kg/cm)	7.34	6.12	6.86	7.10	6.31	6.52