Ecofriendly preparatory processing of cotton textiles

Kushal Desai and Bharat Patel
Department of Textile Chemistry, MS University of Baroda, Vadodara, Gujarat, India
desai.kushal911@gmail.com

The textile industry has played an important role in the development of human civilization over several millennia. It is estimated that over 6000 unique compounds are used in the production of textile and apparel products[1].

Ecofriendliness is the basic requirement in the textile wet processing industry. Ecological aspects can be met by a selection of appropriate chemicals and dyes instead of source toxic and harmful chemicals and dyes for the wet processing of textiles. Any industrial activity causes pollution in one or other and so does the textile industry. The impact of textile production on the environmental aspects such as air, water, land, human body and social aspects such as child, labour and poor un-hygienic working conditions must be considered. Recently, another dimension is introduced for the environmental friendliness of the finished product. This includes the ban on azo dyes which are known to be carcinogenic and contain harmful chemicals such as formaldehyde and certain metals. A large number of chemicals in vast quantities are used in textile wet processing to satisfy consumer's demands as regards to aesthetics, handle, imparting desirable properties etc. Some of these chemicals such as dyes and finishing agents remain attached to the textiles, whereas a substantial proportion of these chemicals remain in the processed water as pollution. Many of the dyes and finishing agents remaining on the finished fabric have been found to pose health hazards. That is why government authorities and the textile industry have taken several measures to reduce the pollution and potential health hazards originating from the textile industry[2].

The various processes used in the textile processing industry contribute to a major portion of the environmental pollution. The textile wet processing industry usually generates a large volume of effluents, which are complex in nature and variable both in regards to quantity and characteristics. The wastewater from the textile industry is known to be strongly coloured, presenting a large amount of suspended solids, pH broadly

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fluctuating, high temperature, besides high chemical oxygen demand (COD). Colour is also a psychologically very important factor in water pollution. The discharge of highly coloured waste is not only aesthetically displeasing, but it also interferes with the transmission of light and upsets the biological processes which may then cause the direct destruction of aquatic life present in the receiving stream. Various attempts are made to reduce the pollution load.

The need of innovations for pollution reduction has arrived due to:
- Increased environmental awareness
- Government legislations
- Global competition[3].

Concept of eco-friendliness

In the present competitive market, environmental awareness is a must for each industry to keep alive its prospect and diversification. The textile industry plays a major role in this eco-awareness program. The word 'eco' is nothing but the ecology that refers to the animals, including human beings and plants in their environment. The environment refers to the conditions surrounding us. Ecology is the study of the interaction between living organisms and their environment, which includes atmosphere, water, and pollutants.

The meaning of ecofriendly is to use such dyes, chemicals and processing ingredients that are biodegradable and have no contents of harmful hazardous/ toxic ingredients. Ecofriendly means not only environmental protection, but also energy conservation[2].

Many chemicals currently used in the textile and chemical industry influence the environment. Sometimes these chemicals can be substituted by other chemicals. The main environmental issues associated with the textile industry arise from emissions to water. The changing face of environmental legislation is causing serious problems for industries and the textile industry is no exception. Worldwide environmental problems associated with the textile industry are typically those associated with the water pollution caused by the discharge of untreated effluents and the use of toxic chemicals, especially during processing. These chemicals can harm the consumer if retained in the fabric.

The eco norms are also becoming stringent these days. Thus, it is increasingly becoming necessary for the industry to adapt to the novel trends which are benevolent to nature. Hence, it becomes essential to study the uses of chemicals and their eco substitutes in detail from the environmental point of view[4].

Testing of eco-parameters

Consumers are becoming more conscious concerning green activities, non-toxic and environmentally friendly consumer goods. They prefer products that pose no threat either to themselves or the environment. This trend for green consumerism has been extended to textile and apparel products. The products involved are those having potential for direct and prolonged skin or oral contact such as clothing, bedding, towels, hairpieces, wigs, hats, diapers, sanitary products, footwear, gloves, watch straps, belts, purses/ wallets, briefcases, chair covers, toys and so on.

Major European and US textile buyers have responded to this public awareness by viewing their textile products from an ecological standpoint and have established certain requirements for textile products. Textile and clothing manufacturers are encouraged to re-examine the whole life cycle of their products to minimize hazards to humans and the environment at every stage, from manufacture to disposal. They are also asked to pay special attention to the selection of dyes, ensuring that the products are low in formaldehyde, free from pesticides, heavy metals etc[5].

Banned amines

The textile specimen was treated with sodium dithionite in a citrate buffered aqueous solution of pH 6 at 70°C in a closed vessel. The amine released in the process of reductive cleavage was transferred to the t-butyl methyl ether phase by liquid-liquid extraction. The butyl methyl ether extract was then concentrated under a mild condition in an evaporator. The extract was then analyzed by any of the four chromatographic techniques recommended in the German method as below:
- Gas chromatography with mass spectrometer
- High performance liquid chromatography with diode array detector (HPLC-DAD)
- High performance thin-layer chromatography (HPTLC)
- High performance capillary electrophoresis with diode array detector (HPCE-DAD).

Heavy metals

The heavy metals present in the textile product were extracted by artificial acid sweat solution. Alternatively, the textile sample was digested using concentrated HNO_3 by using sophisticated digestion systems such as microwave digestion system. This digested solution was analyzed by using either an atomic absorption spectrometer or an inductively coupled plasma emission spectrometer.

PCP

The sample was extracted with methanol in a soxhlet assembly. The extract was subjected to a multi-step cleaning operation to eliminate the contaminants which were eco-extracted from the sample. It was then acetylated with acetic anhydride. The acetylated phenols in the extract were separated by the capillary column in the gas chromatograph (GL) and were then detected and quantified by Electron Capture Detector (ECD)[2].

Pesticides

Here, the use of chemical fertilizers and pesticides is eliminated. Testing methods for pesticides are:
- Extraction and analysis by gas chromatography with electron capture detector (ECD)

Table 1 : Waterwaste and its impact on the environment		
Process	Composition of wastewater	Nature of wastewater
Desizing	Starch, glucose, Carboxymethyl cellulose, PVA, fats, waxes, acids	High BOD, TDS, slightly acidic
Kiering	Caustic soda, waxes, grease, soda ash, sodium silicate	Strongly alkaline, dark-coloured, high BOD, TDS, temperature
Bleaching	Hypochlorite, chlorine, caustic soda, hydrogen peroxide, acids	Alkaline, temperature
Mercerizing	Caustic soda, wetting agent, acetic acid, peroxide, acids	Strongly alkaline, low BOD, high COD, TDS, temperature
Dyeing	Dyes, mordants and reducing agents viz. sulfides, hydrosulfite, acetic acid etc	Strongly coloured, fairly high BOD and COD, alkaline, TDS, temperature
Printing	Dyes, pigments, starch, gums, oil china clay, mordants, acids, metallic salts	Strongly coloured, fairly high BOD and COD, alkaline, TDS
Finishing	Traces of salts, tallow, crosslinking agents, softeners	Slightly acidic, low BOD

Table 2 : Pollution load at a different stage of textile wet processing						
Parameter	Desizing	Kiering	Bleaching	Mercerizing	Dyeing	Printing
pH	8.6-10	10.9-11.8	8.4-10.9	8.1-9.8	9.2-11.0	6.7-8,2
TDS (mg/l)	5580-6250	12260-38500	2780-7900	2060-2600	3230-6180	1870-2360
SS (mg/l)	2290-2670	1960-2080	200-340	160-430	360-370	250-390
BOD (5d, 20°C, mg/l)	1000-1080	2500-3480	87-535	100-122	130-820	135-1380
COD (mg/l)	1650-1750	12800-19600	1350-1575	246-381	465-1400	410-4270

- Gas chromatography with mass spectrometer can be used as a supplementary method.

Textile wet processing

Impact of effluent[3]

Textile manufacturing is one of the largest industrial users of process water and substantial quantities of complex chemicals. In the industries, water is contaminated with different chemicals and auxiliaries, such as dyes, mineral, and organic acids, alkali, sequestering agents, salts, optical whiteners, sizes, non-biodegradable surfactants, formaldehyde-based products etc which are used at different processing stages in units.

The direct discharge of effluents on water bodies such as rivers, ponds, streams, lakes etc pollute the water. The polluted water is harmful to flora and fauna due to high BOD, COD, pH, temperature, colour, odours, turbidity, and toxic chemicals. The commonly used chemicals, the wastewater produced from some of the processes and their impact on the environment are presented in *Tables 1 & 2*. The pollution load of different chemical processing treatments are given in *Table 2* [3].

Impact of harmful chemicals[3,4,6,7]

Textile, which is indeed our 'second skin', was basically intended to protect the human body, but the demand of the consumers kept on increasing, and the textile industry has to meet the modern tastes in fashion, comfort and price which surplus the human health. Environmental pollution is a term that refers to all the methods by which people pollute their environment. It is an undesirable change in the physical, chemical or biological characteristics of the environment which causes harmful effects. Environmental pollution is one of the most serious problems faced by the mankind.

There are some chemicals which are highly toxic and heavily used in the textile chemical processing industry and, as per government rule, they are to be phased out. These are:

- Chlorine bleaches - used in bleaching
- Benzidine based dyestuff
- Acetic acid - used in the neutralization of all processes
- Starch-based warp size - used in sizing
- Kerosene - used in pigment printing
- Formaldehyde, polycarboxylic acid - used in finishing
- Pentachloro phenol - used as preservative, fungicide antimicrobial,
- 1,2 dichloro ethane - used as a solvent for fats and oils in stain removers
- Carbon tetrachloride - used as a solvent in scouring and stain removers
- Pentachloro bi phenyl - used as a flame retardant
- 1,1,1 trichloroethane - used as solvent and cleaning agent
- Nonylphenol ethoxylates - used as a surfactant, emulsifying agent, and in detergents
- Tris(2,3 dibromopropyl)-phosphate - used as flame retardant
- Triphenyl phosphate - used as plasticizers, in flame retardants.

Besides these harmful chemicals,

Table 3 : Effluent specifications norms by GPCB and MPCB			
Parameter	Raw effluent of textile wet processing	GPCB norms	MPCB norms
pH	6-10	6.5-8.5	6.0-8.5
Temperature(°C)	35-45	40	-
TDS (ppm)	8000-12000	2100	1500
BOD (ppm)	300-500	100	100
COD (ppm)	1000-1500	250	250
TSS (ppm)	200-400	100	100
Chloride (ppm)	3000-6000	600	-
Free chlorine (ppm)	<10	1.0	1.0
Oil & grease (ppm)	10-30	20	10
Traces elements (Fe, Zn, Cu, As, Ni, B, F, Mn, V, Hg, PO_4, CN) (ppm)	<10	0.1-3.0	0.1-3.0

several routine chemicals are excessively used than the required quantity which produces heavy effluent[3].

Comparison of effluent specifications by GPCB and MPCB[8,9,10]

The typical raw effluent characteristics of textile wastewater are presented in *Table 3*. The parameters require much attention to implementing a good wastewater treatment scheme.

Comparison of eco parameters by different eco-labels on textiles[11]

Different eco-parameters like core pH, free formaldehyde content, residual pesticides, PCP, heavy metals etc are standardized by different eco-labels called as Oeko tex 100, GOTS, Eco mark, MST, etc for baby clothing and textiles.

Developments in ecofriendly wet processing

Eco-friendly wet processing implies treatments carried out with biodegradable processing ingredients in wet conditions along with water. Rossari, Clariant and many other companies initiated good environmental practices including In-house Improvements, cleaner production options and pollution prevention planning. Pollution prevention encourages changes that can lower production costs, increase efficiency, avoid accidental and operational releases, reduce treatment and disposal costs, and better protect the environment[3].

Toxic dyes and chemicals used in wet processing of textile goods come in contact with the skin and cause direct damage to health like skin cancer, allergy etc. Therefore, an important step in the preparation of ecofriendly textiles will be the reduction of waste at source i.e. to minimize the use of resources like water and substances that are exhausting. Thus, care has to be taken to eliminate/optimize the use of unsafe chemicals, auxiliaries and dyestuffs.

Therefore, to adopt an ecofriendly textile process, in the key areas of textile wet processing like pretreatments, dyeing, printing, finishing, etc, the process should create minimum pollution load with simultaneous minimum consumption of resources like water, power etc and does not utilize any harmful/hazardous/carcinogenic chemicals[6]. The process can be made ecofriendly through the following techniques[2]:

- Developments in auxiliaries and chemicals
- Developments in machines
- Developments in techniques
- Recycle/reuse/recovery of textile waste, chemicals, and water
- Application of natural resources like natural dye, natural thickener, and natural mordants.

Singeing

Singeing is a dry process, considered as a part of the wet processing. In the case of wet processing of cotton, not a large quantity of water, except for quenching the material after singeing is required. Therefore, this process is environmentally friendly. Cotton material can be improved by an enzymatic treatment called bio-polishing which is a finishing process[2].

Desizing

Sizing imparts stiffness to the fabrics. Both natural sizes (i.e. starches such as potatoes, rice, corn etc) and synthetic sizes (such as PVA, CMC, etc) are used for weaving purposes. Starches are most widely used and contribute high BOD and COD to the effluents. Synthetic sizes are non-biodegradable and can pass through the conventional wastewater treatment systems and often linked to aquatic toxicity in receiving water bodies[3].

The sizes have to be removed from the fabric because they interfere with subsequent processing steps. Three methods frequently used in textile processing are acid desizing, enzyme desizing, and oxidative desizing. Good desizing is the first and most important step to achieve a good and soft washing result. Desizing operations represent a large contribution to the pollution[4].

Techniques to minimize pollution in desizing

- The use of acrylates as a size in place of starch reduces the BOD, due to the recovery of size.
- Starches can be partially substituted by polyvinyl alcohol to reduce pollution in effluents. The use of low viscosity sizes, such as PVA, CMC etc enables the recovery instead of upto 50% of the size in the effluents in this process[4].
- Enzymatic desizing[2,3,4,12] is the most popular and effective method. Starch is hydrolyzed to water-soluble compounds

by enzymes. Enzymes used for desizing are known as amylase. However, this enzyme can only degrade starch to glucose. This is the salient feature of an enzyme. The glucose molecule is completely broken down by this reaction. Most enzymes function best at or near pH 7 at temperatures between 40ºC and 60ºC. Also, salt is necessary for enzymatic treatment. Salt improves the heat stability of the enzymes, and the wetting agent helps in quick wetting of the fabric and better penetration of the enzyme. The enzyme bath is composed as follows:

1-2%	Enzyme
0.5-1%	Common salt
1-3 gm	Non-ionic wetting agent.

The use of newer enzymes, which degrade the starch size to ethanol of anhydroglucose, enables the recovery of ethanol by distillation, thereby reducing the BOD load in the desized effluent considerably. Acids should be replaced by enzymatic and/or oxidative desizing to render the vegetable or animal size water-soluble (hydrolysis); starch from all sources can be removed.

Advantages of enzymatic desizing

- Saves water and time
- Process flexibility like batch, semi-continuous and continuous
- Negligeble strength loss
- Decrease the load in effluent
- Effective removal of size.

Commercially available enzymes for desizing

Many companies like Zytex, Maps India, Rossari, Clariant, Sorbe, Huntsman etc are major amylase enzyme producers in the world[20,22].

Scouring

Scouring is typically performed in an alkaline solution and a high-temperature environment. The removal of natural impurities is based upon saponification at high pH. The removal of natural impurities can be done in a single procedure that can be combined with desizing and/or bleaching. This makes the fabric more absorptive without undergoing any chemical or physical change.

The main processes occurring during scouring are:

- Proteins are hydrolyzed into soluble degradation products
- Simpler ammonia compounds are hydrolyzed to ammonia
- Saponifiable oils are converted into soaps
- Pectose and pectin are changed into soluble salts of pectic or metapectic
- Dust particles are removed and held in stable suspension form in the kier liquor by the detergent present
- Unsaponifiable waxes and oils are emulsified by the soluble soaps formed by saponifiable oils[4].

Techniques to minimize pollution in scouring[2,3,4]

- Recycle or reuse of scoured liquor
- Developments of auxiliaries and chemicals:
  - A reduction of 25% in sodium hydroxide can be obtained by substitution with sodium carbonate.
  - Use of green soda instead of soda ash and caustic soda which is recently developed by CHT.
  - Alkylphenolethoxylates (APEO) in detergents and dispersants should be substituted by readily biodegradable surfactants, or should at least not reach the final effluent. Similar restrictions for other non-readily biodegradable surfactants should be considered.
  - Some ecofriendly chemicals used as a wetting agent/scouring agent/detergent in scouring are commercially available by Zydex, Resil, Clariant and many more companies[13,14,15].

Solvent scouring[2]

In the ICI scouring process, the cotton fabric is passed through the vessel containing trichloroethylene which is kept at near boiling point (87ºC). The fabric is then passed through another vessel where fresh solvent has passing counter current to the fabric. The solvent loaded fabric is then passed through mangle after which residual solvent is removed by steaming. The steam causes rapid evapration of solvent. Trichloroethylene vapour is condensed and returned to the solvent seal where solvent and water are separated in the solvent recovery plant. The cloth is washed and finally squeezed.

Enzymatic scouring[2,3,16,17,12,18]

The enzymatic-scouring treatment is carried out for 1 hr at 40ºC at pH 4-5 using an enzyme. The following enzymes are used for scouring:

- Pectinase acts as pectin degrading enzyme
- Protease for removal of protein
- Lipase enzyme for fats and waxes removal
- Cellulase enzyme for cellulose hydrolysis.

Here, two types of raw enzymes are available: 1) Individual effect enzymes: a particular enzyme gives a particular effect which is applied with a mixture of all enzymes; and 2) Synergistic effect enzymes: the single enzyme is a

Table 4 : Parameters of Bioscouring vs Alkaline scouring

Measure	Bioscouring	Alkaline scouring
pH	5.0-5.5	13-14
Temperature	50-60ºC	90-100ºC
Weight loss	$<$ 1.5%	3-9%
Absorbency	$<$1 sec	$<$1 sec
Mots removal	Nil	Complete
Fibre swelling	No	Yes
Water consumption	40-50%	100%
Energy	50-60%	100%
BOD	25-50%	100%
COD	25-50%	100%
TDS	20-40%	100%

mixture of all enzymes which is applied as a single but effects all enzymes.

Following are the advantages of bio scouring over alkaline scouring:

- Less environmental Impact in terms of TDS, BOD & COD
- Saves energy, water etc
- Eliminates core alkali neutralization
- Improved whiteness and absorbency with reduced strength and weight loss.

The use of caustic soda for conventional scouring causes environmental damage and strength. The use of enzymes can be done for the scouring of cellulosic material which is known as enzymatic bio scouring (EBS) system. Parameters of EBS and conventional method are listed in *Table 4*. Many companies like Americos, Maps, Rossari, Zytex etc are commercially manufacturing these enzymes.

Bleaching

Almost all fabric containing cellulosic is being bleached to remove the natural coloured matter. After scouring, cotton becomes more hydrophilic. However, the original colour stays unchanged due to coloured matter that cannot be completely removed by washing and alkaline extraction. Three chemicals are commonly used:

- Hydrogen peroxide (H_2O_2)
- Sodium hypochlorite (NaClO)
- Sodium chlorite ($NaClO_2$)[4].

Techniques to reduce pollution in bleaching[4,9]

- Fabrics that need to be coloured in deep shades should not be bleached extensively, thus reducing the consumption of bleach and consequently reducing the pollution load.
- The use of continuous bleaching ranges, to replace batch preparation of fabrics, reduces water and chemical consumption and consequently contributes to less pollution load. Combined scouring and bleaching of cotton by a continuous range.
- Peroxide bleaches should be used instead of reductive sculpture containing bleaches which are more hazardous hydrogen peroxide (H_2O_2) should be used as the bleaching agent in preference to chlorine-containing compounds, such as hypochlorite. Also, the use of hypochlorite is banned by many certifying agencies. Hydrogen peroxide also minimizes the content of the hazardous organohalogen substance in the final effluent, and eliminates a toxic and hazardous chemical from the workplace and improves the working environment.
- Developments in auxiliaries and chemicals:
  i) Sequesting agent[15]: Organic chelating agent with polyphosphonate derivatives designed to be primarily used as a water softening agent. Excellent stability to acid, alkaline, oxidative and reductive conditions of use. Good compatibility with most textile auxiliaries. Enhances the degree of white during peroxide bleaching.
  ii) The stabilizers, wetting agents, emulsifiers, surfactants, and all other organic chemicals should be readily biodegradable without producing metabolites, which are toxic to aquatic species[9].

Ecofriendly chemicals used for bleaching of cellulosic textiles with their specifications trade names are commercially available by companies like Clariant, Dupont, Zytex etc[20,13,14].

Enzymatic bleaching[2]

In enzymatic bleaching, first peroxide is generated by glucose oxidases (GOD) enzyme which is a flavoprotein. GOD has a flavin adenine dinucleotide (FAD) as an active side. This enzyme is highly specific for Is - D - glucose and catalyzes the reaction for hydrogen peroxide generation at pH 4.5-7 and temperature of around 40°C.

B-D-Glucose+GOD-FAD $\longrightarrow$ GOD+ ADH_2+d-D-Gluconolactone-GOD-$FADH_2$

GOD - + ADH_2 - O_2 $\longrightarrow$ GOD - FAD + H_2O_2

In the presence of water, d-D-Gluconolacton forms D - Gluconic acid, which serves as a sequestering agent during the bleaching process. The treatment time and concentrations of GOD and glucose in the bleach bath are varied. Thus, after generation of H_2O_2, actual bleaching is 85 - 90°C for 60 -120 min.

Bio bleaching vs conventional bleaching[3]

The advantages of bio-bleaching of textiles over conventional bleaching are mentioned in *Table 5*.

Table 5 : Advantages of bio-bleaching and disadvantages of conventional bleaching

Advantages of Bio-bleaching (Laccase)	Disadvantages of Conventional bleaching
• Time saving • Enhanced abrasion without stones • Reduced backstaining • Minimum strength loss • Grey cast • Easy process control • Clean technology	• Problem of yellowing due to leftover chlorine • Offensive odour of Chlorine • Strength loss • Non-ecofriendly • Causes problem of AOX

Commercially available enzymes for bleaching[21,13]

- Biofinase BP-300: Effective bleaching is obtained at as low as 30°C, and the optimum pH 7 yields whiteness values close to chemically bleached cotton; significantly softens 100% cotton fabrics, both woven and knits.
- Peracetic acid bleaching[2,19,22]: Peracetic acid is prepared by reacting hydrogen peroxide with either acetic anhydride or acetic acid.

$CH_3COOH + H_2O_2 \longrightarrow CH_3COOOH + H_2O$

The bleaching of cotton fibres with peracetic acid is catalyzed by incorporating 2,2'-bipyridine and sodium lauryl sulphate (SLS) in the bleach solution. An effective bleaching is obtained at temperatures as low as

30°C and the optimum pH is 7. Bipyridine combines with the natural iron (ferrous ion) present in the cotton and forms trischelates. Trischelates are ionically associated with the fibres.

Bipyridine + Ferrous ion present in cotton ⟶ (Cell - O -)$_2$ Fe (Bipy)$_3$ (Trischelale)

Also, the bipyridine concentration must be sufficient for the complete formulation of trischelates as opposed to mono and bischelates for optimum bleaching. The per-acetate anion is attracted to the coordination sphere of the trischelate where it is close to the colour impurities in the fibres and its reactivity is also improved. Also, SLS reduces the wasteful decomposition of peracetic acid by the combination of trischelate. Trischelates of ferrous ions in the fibres are most effective in catalyzing bleaching. Peracetic acid formed in situ in solution from H_2O_2 and CH, CO, can be catalyzed to bleach cotton fibres at temperatures as low as 30°C by incorporating 2% bipyridine and SLS.

- Use of ozone gas in the bleaching of cotton textiles: Ozone, composed of three atoms of oxygen, can be used to oxidize many inorganic and organic impurities. Because of its high oxidizing capacity, the opportunities and parameters of ozone gas used in bleaching of cotton fabrics were researched in this study. It was found that, in very short time, cotton fabrics can be bleached if the water content of cotton-woven fabric was 60% and the pH of the water impregnated was 7. Moreover, ozonation at room temperature was shown to be more efficient than ozonation at high to medium temperatures.
- Peroxide killers[3,23]: After bleaching, if the residual peroxide on the fabric is not neutralized, then it results in fabric tendering and patchy dyeing. Conventional reducing agents used for peroxide neutralization are non-eco-friendly as they increase the TDS of the effluent. Catalases, on the other hand, catalyze the breakdown of hydrogen peroxide. Each molecule of catalyst is capable of processing around five million molecules of hydrogen peroxide per second. Ultrox series used effectively neutralizes residual peroxide and hence avoids problems in further processing. An alternative to decrease the consumption of water, energy and time is the use of catalyst, which catalyzes the decomposition of hydrogen peroxide as follows:

$H_2O_2 \longrightarrow H_2O + ½\ O_2$

Apart from their specificity, high catalytic power and eco-friendliness, they do not interfere in dyeing; hence dyeing can be continued in the same bath. Some enzymes used as peroxide killers are commercially available by Clariant, Maps etc[13,14,12].

- The installation of holding tanks for bleach bath reuse, where the bath is reconstituted to correct strength after analysis by titration. Using this technique decreased BOD over 50%, reduced the water use, etc.
- Hydrogen peroxide in effluents from bleaching can be reused in the treatment of the (combined) wastewaters as a clean oxidant in the activated sludge process or chemical oxidation processes.

Mercerizing

Mercerization is the treatment of pure cotton fabrics or yarns with a strong caustic soda solution (usually 280-300 gm/l) to improve strength, dye substantivity, strength, and smoothness. The effects of mercerization:

- Improved lustre
- Increased ability to absorb dye
- Improved reactions with a variety of chemicals
- Improved stability of form
- Improved strength/elongation
- Improved smoothness[4].

Techniques to minimize pollution in mercerizing

- Liquid ammonia is a low pollution substitution for conventional mercerisation (NaOH). Heavy cotton fabrics treated with liquid ammonia require less dye for a given depth of shade and consequently contribute to pollution abatement due to using less chemical for the same requirement.
- Alkali should be recovered and reused after regenerative treatment to remove dirt (coagulation, flotation, microfiltration, nanofiltration etc) and after concentration. Dilute alkali from mercerizing should be reused in scouring, bleaching or dyeing operations, so that discharges from alkaline treatment can be minimized, resulting in less pollution effluents.

Recovery of NaOH[2]: Recovery of NaOH from waste in several large mills saves appreciable expenditure and NaOH. The recovery of caustic results in an appreciable reduction of effluents characteristics like pH and TDS. NaOH recovery is carried out by using multiple-effect evaporator, dialysis and reverse osmosis.

- By counter-current washing system
- Biotechnology in mercerisation[12]: Buschle-Diller and Zeronian worked on enzymes and provided alternatives to the alkalis used today.
- By using non-cyclic types of the wetting agents which are biodegradable[21,24,13,14].

Some non-cyclic types of wetting agents commercially available for the mercerizing process are from CHT, Clariant, Zydex etc.

Conclusion

Textile wet processing industry, being the chief cause of pollution, needs to be looked carefully from the ecological point of view. Eco-substitutes for these chemicals will not only help the consumer but also the society, which is directly affected by it. Also, a close look at the worker's safety should be done, since they are the first to get affected by any immediate exposure. Some substitutes are even better and economical as far as their precursors are concerned. Hence, the use of such products should not be delayed. From the environment and ecological point of view, the use of enzymes also serves as substitutes, especially for the preparatory process. The motto of the textile process should then be 'substitution is better than cure'.

The worldwide consumption of cotton will increase due to its comfort properties, cost-effectiveness and environmental friendliness. The problem that the textile industry is facing is of effluent and waste disposal. Also, the red-listed chemicals and banned dyes are carcinogenic and/or highly toxic. It is the number of contaminants present in the final product which causes the harmful effects on the human body. On the other hand, with increasing awareness for the quality of the environment, the environment-related regulations are becoming stricter day by day the world over.

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AD

Separating volatile organic compounds

Specialty chemicals company Evonik's PuraMem VOC is a membrane technology for separation of volatile organic compounds (VOCs). The PuraMem VOC offers a polymer-based membrane technology for efficient separation of longchain hydrocarbons from a natural gas or nitrogen mixture. The spiral-wound membrane module has been optimised for applications such as natural gas treatment, emission control in tank farms, and in the chemical and process industries. It shows consistently high selectivity over a long period under demanding operating conditions.

The membrane technology works according to the different molecular sizes of the substances to be separated. The gas mixture streams through the membrane at a pressure of up to 80 bar, and the larger VOC molecules pass through the membrane while the smaller gas molecules are retained.

The design of PuraMem VOC allows it to be incorporated into the existing infrastructure of the system. The standard 8 inch diameter and the flexible gasket or integrated Kwik-Flange adapter have been designed to make it simple to plug in or drop replacement modules into existing systems.

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RESEARCH

PRE-TREATMENT OF COTTON AND VISCOSE RAYON TO MINIMISE WATER CONSUMPTION AND EFFLUENT LOADING

Kushal Desai*
Department of Textile Chemistry, The Maharaja Sayajirao University of Baroda, Vadodara- 390011
Bharat Patel
Department of Textile Chemistry, The Maharaja Sayajirao University of Baroda, Vadodara- 390011

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ABSTRACT

Textile wet processing industry being the chief cause of pollution needs to be looked carefully from an ecological point of view. Eco-substitutes for these chemicals will not only help the society but also the consumer, which is directly affected by it. Worker's safety should be affected, since they are the first who catch by immediate exposure. Some of the substitutes are even economical and better as far as their pioneers are concerned. From the environment and ecological point of view, use of enzymes like Amylase and Pectinase also serves as substitutes, especially for the pre-treatment process. The slogan of the textile process should then be "Substitution is superior to cure". The worldwide consumption of cotton is going to increase due to its comfort properties, cost-effectiveness, and environmental friendliness. The problem the textile industry facing is of effluent and waste disposal. On the other hand, with increasing consciousness for the quality of the environment, the environment-related protocols are becoming stricter day by day world over. We have polluted our environment in the last 150yrs. Time to take steps to save our planet earth and make regulations and laws to strictly enforce the same, or else like J. Krishnamurthy says, "our present is because of what we were in the past and our future is what we are in the present". Change now or there is no way mankind will be saved. We are doomed to extinction

* Corresponding author.
E-mail:desai.kushal911@gmail.com

1 Introduction

In the previous century, the landscape of India was reshaped by rapid Industrialization. The sky, land, and water became highly polluted with chemicals used in different manufacturing processes. The urban Industrial culture damaged Indian's Traditional style of "How to walk with nature". The Enlightened citizens consider this as a darker side of the changes and emphasize on Sustainable development.

The environmentally friendly processing will include the selection of environmentally acceptable chemicals during processing, health considerations during storage, handling, and application of chemicals, and problems of their discharge in wastewater. There is not enough awareness of these vital problems among top managers, technologists, and chemical manufacturers, despite the information explosion in the present world. It has become the prime duty of researchers to create a sustainable world through innovation in different products and developments in processes that can consume less water simultaneously reduce the effluent loading in the textile wet processing industry.

The textile wet processing industry is always criticized for its consumption of water in its various process sequences i.e., desizing, scouring, bleaching, mercerizing, dyeing, printing, and finishing which subsequently contribute to the environmental pollution. The textile processing industry usually generates a huge volume of effluents, which are composite in nature and variable both in terms of quantity and physical characteristics. The effluent from the textile industry is known to be strongly colored presenting a huge number of suspended solids, pH broadly fluctuating, higher temperature, besides higher COD. Colour is also a sensitively very important factor in water pollution. The discharge of highly colored waste is not only visually offensive, but it also interferes with the spread of light and upsets the biological processes which may then cause the destruction of aquatic life present in the receiving area. Various efforts are made to reduce the pollution load. The need for inventions for pollution reduction has arrived due to:

- Increased environmental consciousness
- Government legislations
- Global competition [1]

2 Concept of Eco-Friendliness

In the present competitive market, environmental awareness is a must for each industry to keep alive its prospect and diversification. The textile industry plays a major role in this eco-awareness program. The word eco is nothing but the ecology that refers to the animals including human beings and plants in their environment. Ecology is the interaction between living organisms and their environment, which includes atmosphere, water, and pollutants.

The meaning of eco-friendly is to use such dyes, chemicals, and processing ingredients that are biodegradable and having no contents of hazardous/toxic ingredients. Eco-friendly means not only environmental protection but also energy conservation [2].

Many chemicals used in the textile and chemical industry influence the environment. Occasionally these chemicals can be substituted by other chemicals. The main environmental issues related with the textile industry get up from releases to water. The changing face of environmental regulation is causing serious problems for many industries and the textile industry is no allowance. A new parameter that today gradually vital is ecology. The logo of eco-labeling is becoming an important factor. Worldwide environmental problems associated with the textile industry are typically with the water pollution caused by the discharge of untreated effluents and those because of the use of toxic chemicals. These chemicals can also harm the consumers if retained in the fabric.

The eco norms are also becoming stricter these days. Thus, it is increasingly becoming necessary for the industry to adapt to the innovative trends which are kind to nature. Hence it becomes necessary to study uses of chemicals and their eco substitutes in detail from an environmental point of view [3].

3 Present Status of Research in The Subject

Eco-friendly wet processing means treatments carried out with biodegradable processing ingredients in wet conditions along with water. Zydex, Rossari, Clariant, and many other companies initiated good environmental practices including In-house Improvements and cleaner production options and Pollution Prevention Planning. Pollution prevention inspires changes that can lower production costs, increase efficiency, avoid accidental and operational releases, ease treatment and disposal costs and better shield the environment [1].

Rachana & Ravindra found that When the scouring and bleaching process baths were recycled, 36 % excess utilization of alkali in the scouring process was observed when compared with the conventional process whereas, in bleaching, 30 % excess usage of alkali and approximately 26 % of that of hydrogen peroxide was seen. The fabric properties after recycling remained unaffected. When the scouring and bleaching process water having unexhausted alkali and hydrogen peroxide was reused to desize a new grey fabric, there was a 10- fold rise in absorbency and 2.7 times rise in WI. Considering the economical perspective, for processing 1-ton fabric/day, there was a saving of 74 % energy, 83 % water and 101542 INR. By properly understanding the waste stream, we can generate new resources for water and chemicals. This will decrease the consumption of fresh water and minimize the load on the effluent treatment plant [4].

Petra Forte studied the intake of water and energy is the lowest at one-bath processes of scouring/bleaching with pectinases and PAA. The whiteness of fabrics is higher than at two-step scouring and bleaching with PAA, but lower than at bleaching with HP. The fabrics have good water absorbency, the fibers are not damaged, and the remaining baths are biodegradable [5].

Dr. T Ramachandran and T Karthik suggest application of biotechnology in textiles includes the potential for novel industrial processes, renewable raw materials, genetic engineering, and effluent management. Enzymes are not active themselves but are complex chemical catalysts. Genetic engineering is one of the techniques in recent biotechnology which directly modifies the command of DNA molecules [6].

Toxic dyes and chemicals which used in wet processing of textile are coming in contact with the skin and affecting direct damage to health like skin cancer, allergy, etc. Therefore, a significant step in the preparation of eco-friendly textiles will be the reduction of waste at source means minimize the use of resources like water and chemicals that are exhausting. Thus, care has to be taken to eliminate the use of unsafe chemicals/auxiliaries/ dyes.

Therefore, to adopt an eco-friendly textile process, the key areas of textile wet processing like pretreatments, dyeing, printing, finishing, etc. the process should create minimum pollution load with simultaneous minimum intake of resources like water, power, etc. and do not utilize any harmful/ hazardous/ carcinogenic chemicals [7].

4 Objective of The Research and Methodology to Be Adopted

Under this background the proposed research & plan of work will concentrate on the following areas:

1. Establishing a suitable process formulation for the environmentally friendly pretreatment processes for cellulosic textiles like low GSM cotton and Viscose. To formulate solutions for the desizing& scouring process with polymers, enzymes, soda, etc. The formulation will be standardized and optimized in terms of their performance at the end of individual steps of pretreatment of cellulosic textiles.
2. Testing of pretreated textiles in terms of change in their properties.
3. Analysis of water consumption in the preparatory processing of cellulosic textiles. Quantitative and qualitative analysis of water required in a series of preparatory processes in terms of COD, BOD, and TDS. The results of water analysis will be compared with the water analysis results obtained from

5 Plan of Work

The experimental plan was based on formulating liquor for sequential preparatory processes for cellulosic textiles, which can consume less water, subsequently, reduce the effluent loading. The experiment has been a plan in four parts as follow:

To formulate solutions for desizing, scouring and bleaching process with enzymes, green soda, organic amines, peracetic acid, etc. The formulation will be standardized and optimized in terms of their performance at the end of individual steps of pretreatment of cellulosic textiles.

The pretreated samples will be evaluated in terms of their morphological, physical, and chemical properties. The change in their properties was evaluated by SEM, EDX, FTIR, and various instrumental methods for testing physical properties using the standard method.

Quantitative and qualitative analysis of water required in a series of preparatory processes in terms of COD, BOD, and TDS. The results of water analysis will be compared with the water analysis results obtained from conventional sequential pretreatment processes.

Finally, the effluent collected from the new pretreatment process will be evaluated in terms of their compatibility and toxicity in water.

6 Materials and Methods

i. Eco-friendly products formulated for pretreatment of Cotton and Viscose
   a. Polymeric Wetting agent/ cleaning agent (PWA)
   b. Desizing agent (DA): Formulated product with Amylase Enzyme
ii. Grey Fabric and Machine for bulk trial
   a. Viscose Woven fabric: Dry singed fabric; Construction – 30 X 30 / 68 X 68; GSM – 103.06; GLM – 174.68; Width – 169.5cm.
   b. Viscose knitted fabric Combed fabric; Count – 34s; GSM – 240
   c. Cotton woven fabric: Dry singed; Combed fabric; Count – 30s; GSM – 85
   d. Cotton knitted fabric: Carded Fabric; Count – 36s; GSM – 180

i. After achieved lab trials of viscose woven, viscose knitted, and cotton knitted fabrics, going for bulk trial in Soft flow machine whereas bulk trial in jigger machine for woven fabric.

7 Results and Discussion

I have taken different lab trials with different fabrics of Cotton and Viscose rayon fabrics. This new process lab trial results are encouraging compared to the current process. On the bases of the lab trials, I will go for bulk trials in the textile wet processing industry.

7.1 Case Study 1: Industrial trial of 100% Viscose Woven fabric in Soft Flow Machine

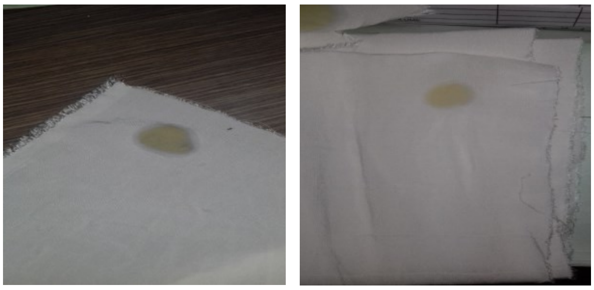

Figure 3 Result of Case study 1

In figure 3, left side is Tegewa stain on Current processed 100% viscose woven; Right side is Tegewa stain on New processed 100% Viscose woven.

Table 1 New and Current Process parameter comparison of100% Viscose rayon woven fabric

Sr. No.	Process parameters	Current process	New process
1	pH of process bath	5-6	7
2	Effective TDS of process bath	1100-1200	750 - 800
3	Total Processing Time (Hrs.)	3	2
4	Processing Temperature (°C)	85	65
5	Washing Temperature (°C)	95	90
6	Total water consumption (MLR)	1:20	1:12
7	No. of washes Pre and Post washes	4	2

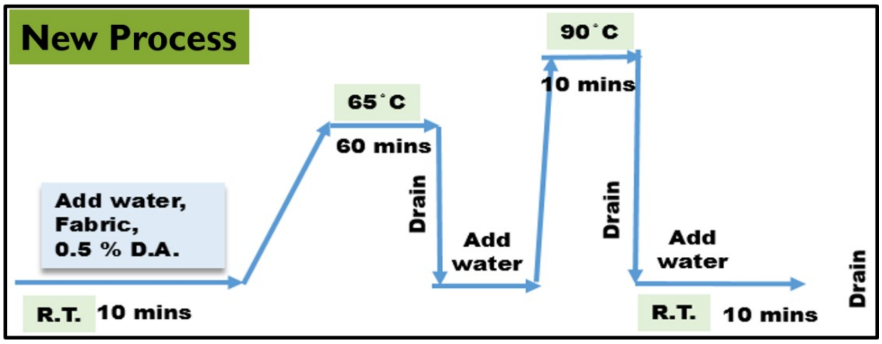

Figure 1 New process flow chart of 100% viscose woven fabric in soft flow machine

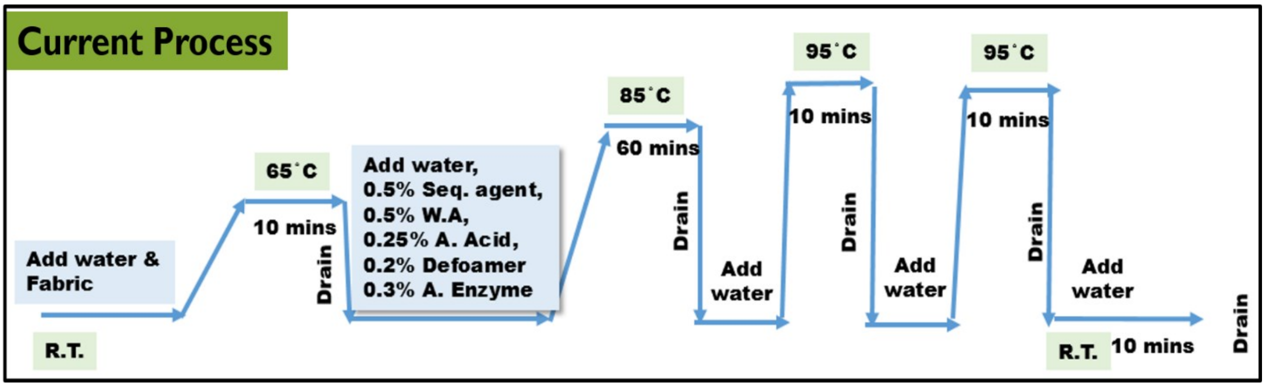

Figure 2 Current process flow chart of 100% Viscose rayon woven fabric in soft flow machine

Table 2 Result of Case study 1

Sr. No.	Properties	Current process	New process
1	Tegewa rating	9	9
2	Absorbency (Sec)	1	1
3	CIE Whiteness	58	63
4	Feel of fabric	-	Softer & more bulky/bouncy compare to Current process

The new process is shown in the reduction of Processing Time and Temperature as well as a decrease in water consumption. Feel of New processed fabric is excellent compared to current process.

7.2 Case Study 2: Industrial trial of 100% Viscose Knitted fabric in Soft Flow Machine

The new process is doing at neutral pH and lowest TDS and also shown in the reduction of Processing Time and water consumption.

Table 3 New and Current Process parameter comparison of 100% Viscose rayon knitted fabric

Sr. No.	Process parameters	Current process	New process
1	pH of process bath	11-12	7
2	Effective TDS of process bath	1600-1800	800 – 900
3	Total Processing Time (mins)	110	75
4	Processing Temperature (℃)	80	80
5	Washing Temperature (℃)	90	85
6	Total water consumption (MLR)	1:16	1:12
7	No. of washes Pre and Post washes	2	2
8	Neutralization required	Yes	No

Table 4 Result of Case study 2

Sr. No.	Properties	Current process	New process
1	Absorbency (Sec)	1	1
2	CIE Whiteness	57	55
3	Feel of fabric	-	Softer compared to the current process

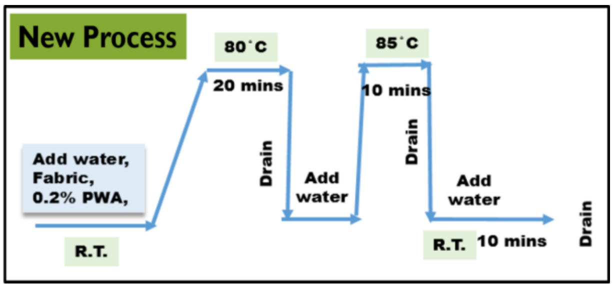

Figure 4 New process flow chart of 100% viscose knitted fabric in soft flow machine

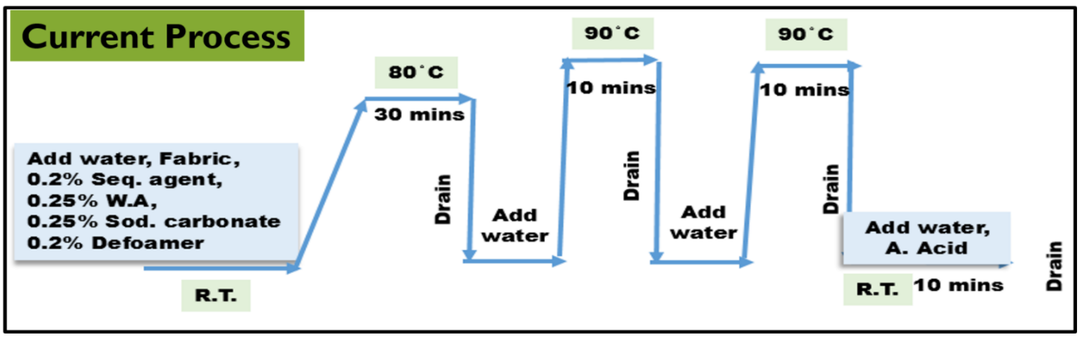

Figure 5 Current process flow chart of 100% Viscose rayon knitted fabric in soft flow machine

7.3 Case Study 3: Industrial trial of 100% Cotton Woven fabric in Jigger machine

Table 5 New and Current Process parameter comparison of 100% Cotton woven fabric

Sr. No.	Process parameters	Current Process		New process
		De-sizing	Scouring & Bleaching	One bath process
1	pH of process bath	5-6	13-14	12-13
2	Effective TDS of process bath	300-400	3500 - 3700	1800
3	Total Processing Time (mins)	3	4-5	6
4	Processing Temperature (°C)	70	95	90
5	Washing Temperature (°C)	80	95	90
6	Total water consumption (MLR)	1:6	1:8	1:10
7	No. of washes Pre and Post washes	1	3	3
8	Neutralization required	No	Yes	Yes, but Less concentration

Table 6 Result of Case study 3

Sr. No.	Parameter	Current process	New process
1	Tegewa rating	9	8-9
2	Absorbency (Sec)	1-2	1-2
3	CIE Whiteness	58	63
4	Feel of fabric	-	Softer & more bulky/bouncy compare to Current process

The new process reduces TDS and is also shown in the reduction of Processing Time & water consumption.

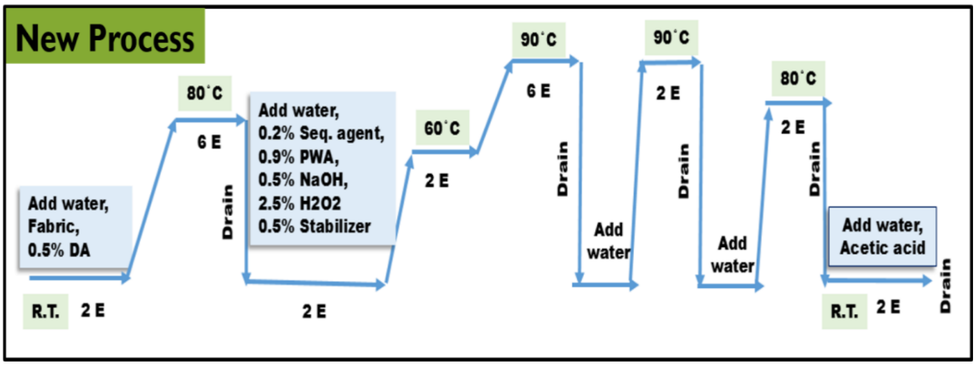

Figure 6 New process flow chart of 100% cotton woven fabric in Jigger machine

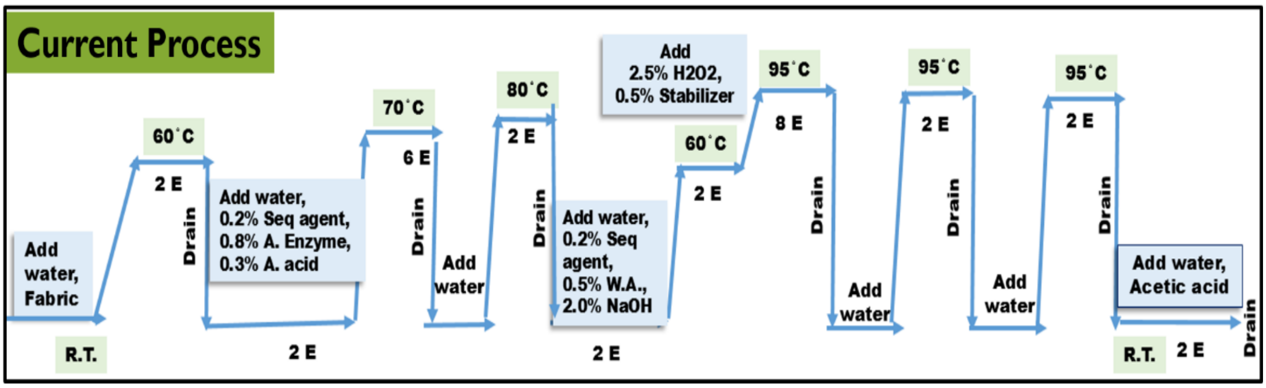

Figure 7 Current process flow chart of 100% cotton woven fabric in Jigger machine

7.4 Case Study 4: Industrial trial of 100% Cotton Knitted fabric in Soft flow machine

Table 7 New and Current Process parameter comparison of 100% Cotton knitted fabric

Sr. No.	Process parameters	Current process	New process
1	pH of process bath	13-14	13-14
2	Effective TDS of process bath	3000 - 3200	1500 - 1700
3	Total Processing Time (mins)	170	140
4	Processing Temperature (°C)	95	90
5	Washing Temperature (°C)	95	75-95
6	Total water consumption (MLR)	1:20	1:16
7	No. of washes Pre and Post washes	4	3
8	Neutralization required	Yes	Yes, but less concentration

Table 8 Result of Case study 4

Sr. No.	Properties	Current process	New process
1	Absorbency (Sec)	2-3	2-3
2	CIE Whiteness	64	60
3	Feel of fabric	-	Softer compared to the current process

The new process reduces TDS as well as reduce Processing Time & water consumption. Feel of the New processed fabric is softer compared to the currently processed fabric.

8 Conclusion

From this case study, it can be concluded that a new approach of pre-treatment is reducing TDS, reducing water consumption, timesaving, and Energy saving. Hence the use of such products should not be late. From the environment and ecological point of view, the usage of enzymes also serves as replacements, especially for the preparatory process. Current

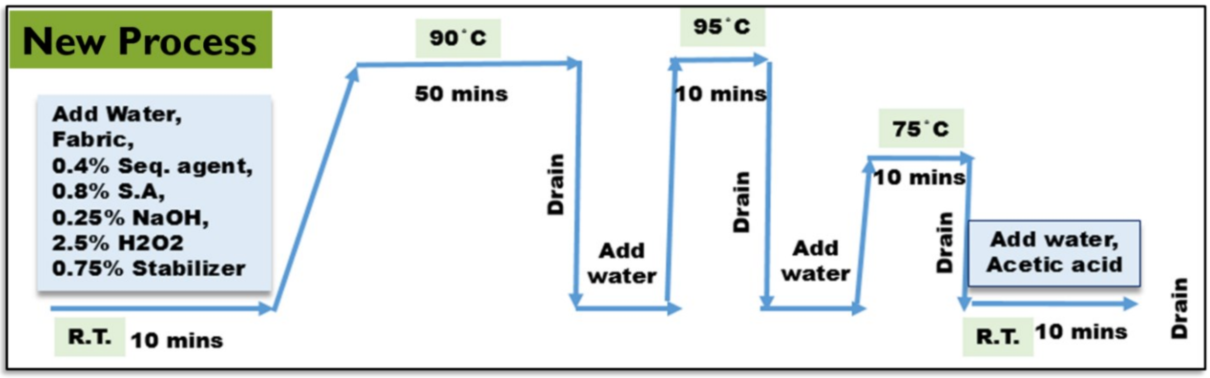

Figure 8 New process flow chart of 100% cotton knitted fabric in Soft flow machine

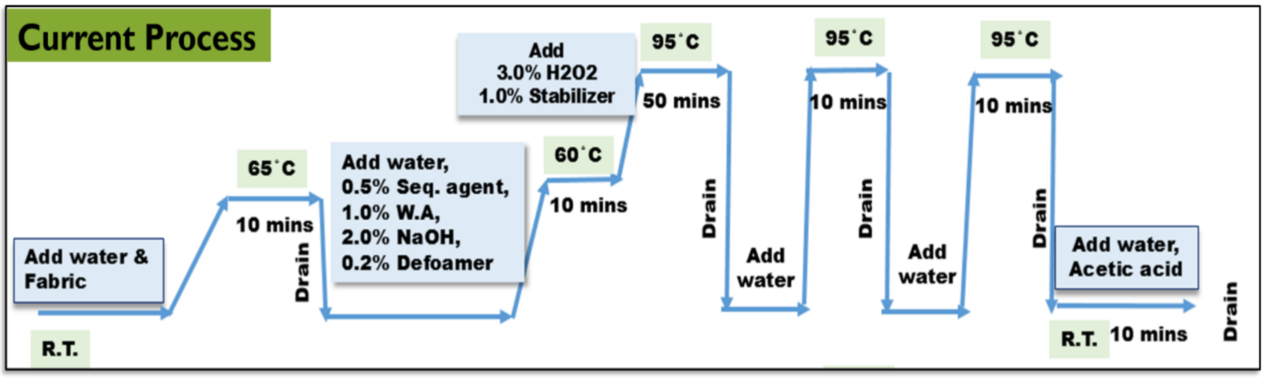

Figure 9 Current process flow chart of 100% cotton knitted fabric in Soft flow machine

industries have polluted the environment and now time to take steps to save our planet earth and make regulations and laws to strictly enforce the same.

9 Future Scope

- The study may be done on other fabrics like Cellulosic blends with Synthetic fabric
- Check Dyeability and Printability after pretreatment
- Involve the concept of Recyclability of liquor for Eco-friendly pretreatment
- Use low concentration or caustic free concept for continuous pretreatment

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Sustainable and innovative cotton processes

By **Kushal Desai, Bharat Patel Ph.D** 15 March 2023

Abstract
Environmentally friendly wet processing is a requirement of the modern textile industry. This includes careful selection of environmentally acceptable dyes and chemicals during wet processing, health considerations during the storage, handling and application of chemicals, and safe discharge into wastewater. To meet these requirements, innovations in the field of dyes synthesis, manufacturing of auxiliary, and innovation in their application technologists is a primary concern for researchers. Stringent rules in dyes and chemical manufacturing industries have to be observed.

Keywords: Eco-friendly, Cotton, Textile processing, Enzyme, Chemical, Pollution.

1. INTRODUCTION

The textile industry has played an important role in the development of human civilisation over several millennia. It is estimated that over 6,000 unique compounds are used in the production of textile and apparel products [1].

Eco-friendliness is a basic requirement for wet processing in the textile industry. Environmental targets can be met by selecting less toxic chemicals and dyes that meet environmental standards for wet processing. The impact of textile production on the air, water, land, and human body must be considered, in addition to good working practices such as child labour, and unhygienic working conditions. .

Another consideration has been recently introduced with the ban on azo dye, which is known to be carcinogenic and contain harmful chemicals such as formaldehyde and other metals. Many chemicals are used in textile wet processing to satisfy consumers' demands for aesthetics and desirable textures. Some of the chemicals in dyes and finishing agents remain attached to the textiles anda substantial proportion of them remain in the processed water, causing pollution. Many of the dyes and finishing agents that remain on the fabric sold have been found to pose health hazards. That is why government authorities and the textile industry have taken several measures to reduce the pollution and potential health hazards caused by the textile industry [2].

The various processes used in textile processing contribute to a major portion of environmental pollution. Wet processing textiles generates a large volume of effluents, which are complex in nature and variable in quantity and characteristics. The wastewater from the textile industry is known to be strongly coloured containing a large number of suspended solids, pH broadly fluctuating, high temperature, besides high chemical oxygen demand (COD). The discharge of highly coloured waste is not only psychologically and aesthetically displeasing, but it also interferes with the transmission of light and upsets the biological processes, which may then cause the direct destruction of aquatic life in the receiving stream. Various attempts are made to reduce the pollution load [3].

2. DYEING

Uniform colouration on textile material using several auxiliary and dyestuff are called dyeing processes. The mixtures are often developed to solve problems specific to the process. Some specialty chemicals are developed to counteract or enhance the effects of other chemicals. In other cases, the specialty chemicals cause side-effects that are detrimental to the overall process. For e English wetting agents are often added to preparation and dyeing steps to ensure the penetration of chemicals. Apart from a few exceptions (eg the thermosol process, pigment dyeing, etc.), most of the emissions originating from the dyeing process are emissions to water. Water-polluting substances can originate from the dyes themselves (eg aquatic toxicity, metals, colour), auxiliaries contained in the dye formulation (eg dispersing agents, anti-foaming agents, etc.). Basic chemicals and auxiliaries used in dyeing processes are alkali, salts, reducing and oxidizing agents, etc. [2], [4].

2.1 Techniques to minimise pollution in dyeing [4]
2.1.1 Selection of dyes
Dyes found to be containing PCBs (eg certain sources of Cu-phthalocyanine), benzidine-based azo-dyes, metal-containing dyes (Cu, Cr, Ni, Co, etc.) should be substituted immediately. The same applies to azo dyes, which - under reductive conditions – can release suspected carcinogens called aromatic amines.

Direct or reactive dyes based on benzidine should be immediately avoided. Dyes based on intermediates such as benzopyrene chloroaniline, dichloro-aniline, and hexachloro pentadiene also have to be avoided in due course. Also, dyes based on copper and chromium metal complex have to be avoided as far as possible.

- Cadmium-containing pigments should not be used.
- To minimise the discharges of BOD, COD, etc., as well as of coloured substances in case of repeated dyeing, the rinsing bath should be used as the next dye bath, if the after-treatment chemicals are compatible with the dye bath chemicals.
- Cationisation of cotton for low salt or salt-free dyeing [2].

Cellulosic fibres, when coming in contact with water, produce a slightly negative charge due to the ionisation of hydroxyl groups. Also, most of the dye classes suitable for cotton are anionics in solutions. The slightly negative charge on the fibres results in the repulsion of anionic dyestuff and thus the exhaustion of the dye bath is limited. However, by adding an electrolyte such as NaCl or sodium sulphate, the charge repulsion factor can be offset, and thus increased dye exhaustion is achieved. Therefore a dyeing procedure leading to high dye fixation could be of great benefit to minimise the environmental problems. Cationisation of cellulose through a chemical reaction with compounds containing cationic groups has been recommended to control the effluent problem. Also, apart from these, the approach of producing fabrics from yarns of cationic and normal cotton has been commercialised by Japanese companies such as Kurabo Industries. Kanebo Textiles and Toyobo. On subsequent dyeing, these fabrics give a differential colour and cross-dye effect. Cotton, Colo-cotton and Viewline are some of the brand names of cationic cotton sold in the international market by Japanese manufacturers.

2.1.2 Minimisation of chemical usage

Some of the approaches to minimise the use of chemicals are:

- Dyeing at a low liquor ratio.
- Right first-time approach.
- Process innovations in continuous dyeing.

2.1.3 Eco-friendly approaches in different dyeing [2], [18], [19, [21]
2.1.3.1 Vat dyeing

- Dyeing with Glucose

Reduction of dyes by sulphide should be avoided and glucose acts as a reducing agent, but it is highly dependent on temperature. The salt potential of glucose is very stable, even at 350^{0}C, and can reduce the total potential of the vat.

Recipe:
Dye X%
Glucose/Dextranil 2 gpl (Reducing agent)

English

NaOH 2 gpl
Sodium sulphate 1.5 gpl

The glucose condition is very effective in preventing the reduction of sensitive dyestuff in the continuous pad – steam process. Dyeing is carried out by conventional method, according to the type of dye class being used for 45 minutes. Then oxidation treatment is given using 1 gpl H_2O_2 at 50^0C for 15 minutes. Finally, soaping is carried out at boil. Dichromate oxidation of vat dyes should be substituted by peroxide oxidation or air oxidation.

2.1.3.2 Sulphur dyeing [29]

- Alternative reducing system than sulphide

Hydrol: Hydrol is the product of sulphur dye. Hydrol contains about 50% reducing sugars. It has a redox potential of 500 mv in an alkaline solution at 80^oC. Also, 65 purls of hydrol along with two parts NaOH can replace 100 parts of Na_2S. Dyeing is generally carried out using the exhaust method in the Jigger trough. The dyeing obtained by this method is equivalent to conventional dyeing in the depth of shades, fastness properties, etc.

Thioglycol: In combination with NaOH, thioglycol may be used in the application of most solubilised sulphur dyes, although the colour yield is lower than from sulphide reduced systems. The advantage of thioglycol is that there is no sulphide and no significant odour from the dye bath.

Glucose/dextranil: 1% stock solution is prepared by taking 1 gm dye paste with 1 ml of T R Oil, to which 20 ml of hot water is added. The solution is boiled and then 3 gpl dextranil or glucose is added with 4 gpl of Na_2CO_3 and 2 gml of NaOH for reduction purposes. Finally, it is made up to 100 ml by adding cold water and used as slock solution.

Mercaptoethanol: Is - mercapto-ethanol marketed by BASF and sold under the trade name Molleskal-SF is a solubilised sulphur dye that can be applied using mercaptoethanol and caustic soda using exhaust methods as well as one bath pad steam process.

Dichromate oxidation of sulphur dyes should be substituted by peroxide oxidation.

2.1.3.3 Direct dyeing

- Avoid after treatment with copper or chromium salts to improve fastness.
- Dye fixing agents based on HCHO should not be used to improve the wet fastness of the dyed material.
- After treatment with cationic dye fixing agent containing less formaldehyde (HCHO).
- Selection of dyes with high fastness.

2.1.3.4 Reactive dyeing
Two main eco-friendly approaches are:

- Modification of the dye to increase the fixation by enhancing the reactivity.
- Modification to increase the substantivity so that the electrolyte requirements are cut down.

Bifunctional reactive dye [2], [33], [50]
Bifunctional reactive dyes consist of two reactive groups capable of forming covalent bonds with the fibre. The bifunctional dyes can be of two types:

a. Homobifunctional reactive dyes
b. Heterobifunctional reactive dyes

Developments in reactive dyes are the sumifix supra dyes (Sumitomo Company, Japan), which are the mixed bifunctional reactive dyes containing both vinyl sulphone and monochloro triazinyl groups. These dyes overcome the drawbacks of a low degree of ex

English >

fixation, poor levelness and reproducibility, and low fastness properties.

ICI developed the I'rocion Supra range with two monochlorotriazine groups per molecule. This is for producing a range of high-temperature dyes for exhaust dyeing with substantially increased exhaustion and fixation. This yields better dye utilisation less hydrolyzed, less efficient. Also, Procion HE (ICI) consists of two monochloro triazine groups for exhaust dyeing with exhaustion and fixation.

Trifunctional reactive dyes [50]
Although relatively few products have been marketed with three reactive groups, increasingly this has been an area of patent interest. Ciba, Sumitomo, Hoechst, and BASF have disclosed several different chromogenic types containing bis-VS/MCT and bis-VS/MFT reactive groups.

Ciba has also claimed dyes with a bis-VS/difluorochloropyrimidinyl, bis-MCT/VS, or bis-MFT/VS combination. Hoechst has recently patented the interesting trifunctional combination of two (masked) vinylsulphonyl groups attached to a single triazinyl ring. Reactive dyes with three halotriazinyl or triazinylpyridinium groups, with VS/MCT plus a difluorochloropyrimidinyl group or with a bis-VS/triazinylpyridinium combination have also been described.

Ciba has filed patents covering a wide range of chromogens with two VS/MCT or VS/MFT reactive group combinations. Similarly, Hoechst has shown interest in reactive dyes with four reactive groups, and once again two pairs of VS/MCT or VS/MFT have been employed to this end. A typical example is the reddish-grey to black chromium complex. Other reactive group combinations have also been described, eg two triazinylpyridinium reactive groups with either two vinylsulphonyl or a-bromoacrylamido or b-chloropropionamido groups. BASF has patented dyes with four monohalotriazinyl groups.

Nevertheless, Hoechst did launch one related dye: Remazol Brilliant Red SBB (CI Reactive Red 181) in 1975. This product is one of the early trifunctional reactive dyes for cellulose.

Neutral fixing reactive dyes [50]
In 1959, chemists at ICI showed that a range of tertiary amines reacts with monochlorotriazines, and with di- and trichloropyrimidines to furnish stable but fibre-reactive quaternary ammonium salts.

The important observation was made that the quaternary ammonium products fixed more rapidly to cellulose than the chloro precursors. This increase in reactivity stimulated much interest in this area for, in the early days of reactive dyeing, this discovery suggested a way of breaking ICI's virtual monopoly on short batching dichlorotriazinyl dyes. Subsequently, catalytic quantities of tertiary amines were used to take advantage of this enhanced reactivity. The idea behind this approach was the recycling of the tertiary amine if the quaternization and fixation/hydrolysis reactions were rapid. Reactive pre-formed quaternary ammonium salts were also patented as fixation catalysts.

In the triazine series, replacement of chloro by a quaternary nicotinic acid group not only enhances reactivity but also allows fixation to proceed under essentially neutral conditions. This is a very important and special feature of this type of reactive dye. Under neutral fixation conditions, the release of an organic base barely affects dyebath pH (unlike, for example, the release of chloride ions in the case of monochlorotriazinyl dyes).

A study by Lewis has shown that good neutral fixation can be achieved for a range of quaternary ammonium groups attached to triazinyl systems. Although the mechanism of the neutral fixation of quaternary ammonium reactive dyes is unclear, it must involve a cellulose deprotonation step. Neither monochlorotriazinyl nor vinylsulphonyl dyes show significant levels of fixation to cellulose when applied at 95°C in the presence of salt and buffered at pH7. While Procion Blue H-EG was recommended to be applied in the presence of sodium carbonate solution, Kayacelon Reacts utilise neutral fixation. In the latter case, the application temperature can be varied at 95°C and 130°C, and high levels of fixation are found.

Acid fixing reactive dyes [14], [50]
Accordingly, few ranges of dyes have been launched that fix to cellulose in an acidic rather than a basic environment. At present all active commercial products, except Kayacelon React dyes (neutral fixing), require basic conditions for fixation. Procion T dyes, based on the chemistry of phosphonic acids, were fixed to cellulose in an acidic environment. However, unlike the acid-fixing groups used in the late 1950s and 1960s, Procion T dyes required an agent to enable the covalent bond formation to take place.

E-control process
Dyeing with highly reactive dichloro triazinyl Procion MX dyes with Na_2CO_3 (developed by Zeneca and Monforts). This is continuous dyeing and involves the fixation of dyes under controlled relative humidity conditions of 25-30% in a hot flue dryer. The dyeing is carried out continuously using a pad-dry-wash sequence. The fixation is as high as that in the pad-steam process.

Low salt dyeing approach to minimise salt load

- Dyeing at a low liquor ratio.
- Dyeing with reactive dyes gives high exhaustion and fixation at low salt concentration.

Cibacron LS dye
Its main features are:

- Bifunctional reactive dyes have medium reactivity, but high dye affinity and high dye fixation.
- Stable dye fibre bond.
- Less dye needs to be removed from the fabric after dyeing.
- The rinsing step is much faster.
- Less water is needed for wash off.
- Less dye effluent.

Polyron SAR [22]
Ecofriendly Soda Ash substitute for fixation of all types of reactive dyes.

Salient features:

- Polyron SAR is an eco-friendly alkali substitute.
- Its addition to a reactive dyeing bath leads to good exhaustion and fixation and therefore a good colour yield on cellulosics.
- The use of Polyron SAR in reactive dyeing makes the neutralization of core alkali much easier and more efficient than traditional alkalies.
- This reduces hydrolyzed dye presence at the consumer end.
- It gives better wash fastness.
- It is suitable for dyeing in all types of machines and all forms of substrate.
- Polyron SAR is a cost-effective replacement for soda ash. Depending on the class of dyes used and the depth dyed, only 1/5th to 1/6th of the quantity of soda ash need to be deployed.
- As the quantity of Polyron SAR used in dyeing, is a fraction of the amount of soda ash required, the amount of acetic acid needed for neutralisation is proportionately less. This leads to lower TDS and consequently, reduces the effluent load on the ETP plant.

Properties:
Physical Appearance – Colourless to a pale yellow clear liquid
Ionicity – Anionic
pH (1%soln.) – 12.5 ± 0.5
Solubility – Soluble in all proportions
Storage stability – 1year if stored in closed containers in a cool

Application:
Depending on the class of dyes, the amount of Polyron SAR can be varied as follows:

English

0.5 – 1.3 gpl for Di chloro triazine (Cold brand dyes).
1.5 – 3.5 gpl for Vinyl Sulphone dyes.
1.5 – 3.5 gpl for Mono chloro triazine (Hot brand) and Bifunctional dyes.

In the mixed alkali system, the quantity of Polyron SAR required is 1/6th that of soda ash, along with the same quantity of caustic.

Compensation for hydrolysis in the re-use of reactive Dyes [13]
In conventional exhaust processes for applying reactive dyes, the alkali accelerates dye hydrolysis, restricting subsequent reuse. Step-up and chemical build-up can complicate accurate colour duplication with reused dyes as well. A two-bath method of first applying the dye from a salt and dye bath followed by treatment in a separate alkali bath eliminates the possibility of alkali-induced hydrolysis, step-up, and chemical build-up effects.

2.1.3.5 Natural dyeing [11], [12], [15]
Natural dyes comprised those colourants (dyes and pigments) that are obtained from animal or vegetable matter without chemical processing. They are mainly mordant dyes although some vat, solvent, pigment, and acid types are known.

Natural dyes can be used in the colouration of textiles, foods, drugs, and cosmetics. Small quantities of dyes are also used in colouration of paper, leather, shoe polish, wood, cane, candles, etc. In earlier days, dyes were derived only from natural sources. But natural dyes suffer from certain inherent disadvantages of standardised application and the standardisation of the dye itself as dyes collected from similar plants or natural sources are influenced and subjected to the vagaries of climate, soil, cultivation methods, etc. Hence for the natural dyes to be truly commercialised and to take a competitive place concerning synthetic dyes, the standardisation methods play a very significant and vital role.

Advantages of natural dyeing:

- Natural dyed fabrics will have more strength than conventional.
- It would have the typical smell of herbs used for processing the same.
- Lime discharges on natural-dyed textiles because it is the strongest source of acid in nature.
- Biodegradability and bio compost tendency.
- The colours may change with the other physical/chemical and external environmental changes.
- They are extremely therapeutic to the eyes and mind.
- Natural-dyed colours are created from plants and minerals. All of the herbs have therapeutic uses as botanicals (herbs), or as homeopathic (diluted), or as nutritional supplements (minerals).
- It is extra smooth and good for transpiration.
- The colours are unique and cannot be duplicated with any dyes, thus new shades are created.

Limitations of natural dyes:

- Low colour yield.
- Long dyeing time.
- High production cost.
- Poor reproducibility.
- Some metallic mordants are hazardous.

3. PRINTING

Printing, like dyeing, is a process for applying colour to a substrate. However, instead of colouring the whole substrate (cloth, carpet or yarn) as in dyeing, print colour is applied only to defined areas to obtain the desired pattern. This involves different techniques and different machinery concerning dyeing, but the physical and chemical processes that take place between the dye and the fibre are analogous to dyeing. Pollutants encountered in exhaust air are:

English

- Aliphatic hydrocarbons (C10-C20) from binders.
- Monomers such as acrylates, vinyl acetates, styrene, acrylonitrile, acrylamide, butadiene.
- Methanol from fixation agents.
- Other alcohols, esters, polyglycols from emulsifiers.
- Formaldehyde from fixation agents.
- Ammonia (from urea decomposition and from ammonia present, for example, in pigment printing pastes.
- N-methylpyrrolidone from emulsifiers.
- Phosphoric acid esters.
- Phenylcyclohexene from thickeners and binders [4].

3.1 Techniques to minimise pollution in printing

a) Use of synthetic thickeners based on polycarboxylic acids instead of kerosene in pigment printing. Kerosene can be substituted by acrylic polymer-based synthetic thickeners. The half of substitution of kerosene by synthetic thickener is comparable to kerosene-based prints.

b) Avoid treatment with hypochlorite for improving whiteness on printed fabrics.

c) Use of pigment printing whenever possible.

d) Pigment printing can be carried out using Sunnyfix NF instead of conventional melamine – a formaldehyde-based fixer. The process is followed by print-dry-cure at 150°C for five minutes.

e) Careful scheduling to prevent expiration of print paste before use.

f) Discharge printing on cotton fabrics using laccase enzyme [16]

The theory of discharge printing involves the degradation by chemical reagents of the chromophore system of the dyestuffs applied to the textile material. There are mainly two types of discharging agents: oxidizing and reducing agents. In discharge printing, The use of zinc sulphoxylate formaldehyde and $SnCl_2$ should be minimised or better avoided by the laccase enzyme. Laccase enzyme formulation has been used in the discharge printing of cotton fabrics dyed with different reactive dyes and the effect of the enzyme at optimum conditions are 4.5 pH, 60°C temperature, hour's time.

g) Print washing with enzyme [3]

A judicious blend of enzymes and surfactants hydrolytically split the chains, bringing down the viscosity and making it easy to wash off the gum. The advantages of enzymatic washing are:

- Excellent specificity: it works only on reactive dye hydrolysate.
- Eco-friendly: biodegradable, leaves rinse bath clear.
- Saves water and energy: it works at 55-60°C.
- Reduces number of rinse baths.
- Cost-effective.
- Excellent quality standards: improves fastness properties.

h) Possible approaches to urea replacement [30]

There are three approaches currently being examined to eliminate or replace urea in cellulose printing:

- Switch to two-phase printing (Flash age printing).
- Complete or partial substitution of urea with an alternative chemical like Matexil FN-T (dicyandiamide).
- The mechanical application of moisture before the substrate enters the steamer.

i) Inkjet printing [34], [47]

This technology is emerging to minimise waste and prevent pollution. Droplets of dye solution are directed onto fabric to form a pattern, eliminating photographic screen making and colour mix kitchen activities.

In all true jet printing systems, the ink is projected onto the surface of the substrate as a coherent and controlled series of drops; it is, therefore, inappropriate to use the phrase 'spray printing', as is sometimes done. Usually, a set of inks is used consisting of at least three or four primary colours – cyan (turquoise), magenta, yellow and optionally black – the so-called CMYK inks. These colours are also employed in gravure and offset lithographic colour printing, although in such applications the three primaries are either printed as dots of varying diameters (amplitude modulation) or as uniformly sized dots of various randomised density arrangements (frequency modulation). Less commonly so-called spot colours may be pre-mixed to match the specific shades in the pattern, as is done in conventional textile printing. As most inkjet printers were originally designed for paper printing, the terms encountered in, for example, technical specifications are more related to those used in the reprographics industry than those that a textile printer would normally employ. Thus reference is usually made to inks rather than dye solutions, pigment dispersions, or print pastes. Similarly, print resolution is usually defined as dots per inch (dpi) or lines per inch (lpi) rather than as mesh or raster.

Today 90% of all printed textiles are produced on rotary- or flat-screen machines, the choice of which system is used depends mainly on the length of fabric to be printed. Particularly in the field of rotary printing, machine design and operation continues to be refined so that, for example, setting up and pattern fitting can now be achieved quickly using laser light alignment devices and individually driven screens, whilst screen changing times can be reduced to as little as 10-15 minutes. So what are the attractions for a total change to a jet printing system? The first reason for increased interest in digital printing processes lies in the very common use of CAD systems, followed directly either by laser engraving or exposure of screens coated with suitable lacquers.

It is even more attractive to eliminate screen making, and such is the possibility offered by direct ink-jet printing of textile materials. The immediate benefits are:

- Very quick customer response for both strike-off and bulk prints and minimised wastage on pre-production sampling.
- No capital tied up in the screens, with major savings in storage space (patterns now stored on CD-ROMs or similar storage media) and damaged screens eliminated.
- The number of colours and the size of the pattern is virtually unlimited, enabling the production of very long repeats (eg fully bordered bedsheets) and full tonal (photorealistic) prints.
- Instant fitting of patterns at start-up, thus minimising fabric and paste wastage.
- Minimal downtime, because pattern changes and also colour changes, when using CMYK inks, are virtually instantaneous.
- Only the ink required for the design is laid down, thus eliminating any waste of print paste.
- The amount of ink applied to the substrate is far less than that used in a screen printing process.

4. FINISHING

Now a day's multifunctional finishes are becoming increasingly important for high-value fabrics. Some of the finishes that are increasingly being used include:

- Wrinkle-free/durable press/easy-care finish.
- Enzyme wash/biofinishing.
- Softeners give better resiliency, bouncy effect and sometimes hydrophilicity.
- Waterproof/stain-repellant but breathable finishes.
- Antimicrobial/deodorant finishes.
- Flame-retardant finishes [52].

4.1 Techniques to reduce pollution in finishing [4]

- Finishing chemicals should be reused whenever possible.
- Biocides such as chlorinated phenols, metallic salts (As, Zn, Cu, or Hg), DDE, DDT, and benzothiazole used in preservation finishing should be substituted by UV. treatment and, or mechanical processes or by enzymatic finishing.

4.2 Eco-friendly approaches in different finishing

4.2.1 Durable press finishes [2], [4], [21]

Cellulosic fibres such as cotton don't have natural bridges or cross-links between them. When deformed under stress (washing or wrinkling) the cellulose chains do not return to their original position. Therefore, durable press finishes are given to the cotton fabrics to impart smooth drying properties and dimensional stability. Cross-linking agents are used to produce wash and wear and durable press properties. They are applied to fabrics that can be washed easily and dried to a smooth state. They exhibit excellent crease recovery. For preparing rein finished fabric, the textile is impregnated with a solution of resin containing a catalyst, dried, and cured at high-temperature. Examples include: Urea-formaldehyde resin, dimethyl dihydroxy ethylene urea.

Problems associated with durable press finish:

- Most of the DP finishes contain formaldehyde as a cross-linking agent. Formaldehyde is a toxic substance when present in gaseous as well as dissolved form.
- Formaldehyde is believed to be carcinogenic and caused lung cancer when the test was performed on rats.
- It is a severe eye irritant that dissolves in eye fluid resulting in inflammation.
- Formaldehyde is carcinogenic when released.
- Free formaldehyde irritates the mucosa and can provoke an allergic reaction.
- Respiratory discomfort due to ammonia vapours can irritate eyes and skin, causing shortness of breath, nausea and vomiting.

Remedy

- Formaldehyde scavengers.
- Efficient local ventilation.
- Control of atmospheric conditions since high temperature and humidity increase the rate of formaldehyde release.
- Extensive use of steam pressing and forming operations in garments forming.
- Partial replacement of N-methylol group with zero formaldehyde content.

4.2.2 Treatment with different cross-linking agents [48]:

a) Treatment with BTCA

b) Treatment with citric acid

c) Treatment with DMDHEU

d) Treatment with Glyoxalz

Advantages of eco-friendly cross-linking agents:

- Bulk production is costly.
- Superior wrinkle-free performance, good laundering durability and high-strength retention.
- Durable press performance equal to that of dimethylol dihydroxy ethylene urea (DMDHEU).
- Also, exhibit from 10% to 20% better retention of fabric strength than DMDHEU.

e) Mothproofing / anti-bacterial finish [4], [52]

- In the case of mothproofing finish, wastewater should be treated in such a way that excessive sludge is avoided. This sludge should preferably be incinerated as chemical waste or detoxified by wet (catalyzed) oxidation.
- Anti Bacteriacide: Piscean AB500. Durable anti-bacterial treatment aids for cellulosic and fabrics. Easy application, durable efficacy. Greatly improves fabric's tear strength over time: Suitably treated cellulosic fabric's antibacterial properties can withstand up to 100 times of home laundry washing.

f) Softening/stiffening [2], [4], [21]

Softeners give a soft feel to the fabric. They are also used with starch and other additives to give softness and body to the fabric. Different types of softeners such as cationic, reactive, and emulsion are available. Except for silicone softeners, all others are temporary

English

and get washed off after two or three washes. Silicones also give water repellency, which is fast to wash and dry clean. It is compatible with other finishing agents and can be easily applied on the cloth. Air porosity is not altered in fabrics treated with silicones.

- Softeners: use minimum quantities and preferably nonionic latex-based, siotex, durafill amino silicon type of acrylics.
- Stiffeners polyvinyl acetate copolymers should be selected to be free from plasticisers such as triphenyl phosphate.

Non–eco-friendly chemical	• Polysiloxanes and derivatives (softening agents) • Quaternary ammonium siloxanes • Fatty acid modified melamine resins
Problems associated	• Many times the exhaustion of the softening agent is low, which causes health problems if the softener is hazardous • Unpleasant odour of the softening agents. • Skin irritation • Softener is not biodegradable
Eco-substitute	• Vinyland acrylic copolymers polymeric softeners • Cellulase enzymes • Epoxy modified silicones
Advantages	• Good results are obtained • Do not require the emulsifying agent

Table 1: Ecofriendly finishing and its advantages

Some eco-friendly chemicals used for softening purposes are [52]

- Cationic softener: Pisoft Q95, Silkysoft 90. Treated goods retain their wetting properties while their softness, hydrophilicity, breathability, and anti-static properties are greatly enhanced. Most products are made from plant extracts and do not contain animal extracts.
- Antiozone softener: AK series. Effective cationic anti ozone softness to treat premature yellowing of indigo denim garments. Imparts protective colloids over indigo dyes and softness to fibres.
- Weak anionic softener: Pisoft QD2000MB. Made from advanced absorbent cosmetic raw materials. Treated goods will yield hydrophilic, fluffy, non-yellowing, high water absorbency, high wicking, and extremely good lubricating effects. Ideal to be used for hosiery, 100% cotton knits, especially on white fabrics.
- Non-ionic polymer softener: Pisoft B200. Prill type concentrated softener which yields lubricating type, the bulky soft hand feels with anti-static properties. Imparts anti-static, strong hydrophilicity, and superior anti-tear, anti-wear strength to treated fabrics.
- Silicone softener: Pisicons WS123E, WS800K, WS128E: Micro to nano-size amino reactive silicone softeners. Applicable from low to high temperatures, yields slick and soft hand feel to treated fabrics at economical costs.
- Softonic Conc: Alkaline pH (up to pH 9.5), high temperatures (up to 95^{o}C) resistant, spot-free silicone emulsions with high active contents. Yields hydrophilic soft hand feel. Non-yellowing.

g) Flame retardants [4], [21]

Fire retardancy involves the disruption of the burning process so that it is terminated within an acceptable period. In designing polymeric flame-retardant, three approaches can be adopted:

English

1. Designing the basic polymer so that exposure to heat and oxygen will not produce combustion. This requires thermally stable polymers with high decomposition temperatures.
2. Transforming the existing polymer with either chlorination or substitution or polyol (this category is called the reactive type flame-retardant).
3. Adding either inorganic salts or organic compounds so that the polymer performs satisfactorily when exposed to fire (this category is called the additive type flame retardants). Silicone is considered a universal additive to improve the flammability properties of polymers. The uniqueness of silicon flame-retardant is that the hydrogen chloride formed in the combustion zone immediately takes part in flame inhibition and is thus very effective. Flammability of a large number of materials is reduced in the presence of relatively small concentrations of silica gel and potassium carbonate.

They are generally applied to cotton and synthetic fibres. In some specific cases, in particular, in the carpet sector, they can also be required for wool, even though this fibre is already inherently flame resistant. Flame-retardant properties are achieved by the application of a wide range of chemicals, which either react with the textile or are used as additives.

Non–eco-friendly chemical	• Organo-phosphorous and polybrominated organic compounds • Halogenated hydrocarbons (bromated diphenyl ethers and heavy metal-containing compounds) • Asbestos
Problems associated	• Possibly carcinogenic • Allergic substances
Eco-substitute	• Inorganic salts and phosphonates
Advantages	• Compatible results are obtained

Table 2: Eco-friendly substitute for flame-retarding finishes

h) Bio-polishing [3], [25]

Cotton and other natural fibres can be improved by an enzymatic treatment called bio polishing. The main advantage of bio polishing is the prevention of pilling. Cellulases hydrolyze the microfibrils (hairs or fuzz) protruding from the surface of yarn because they are most susceptible to enzymatic attack. This weakens the microfibrils, which tend to break off from the main body of the fibre and leave a smoother yarn surface. A ball of fuzz is called a 'pill' in the textile trade. These pills can present a serious quality problem since they result in an unattractive, knotty fabric appearance. After bio polishing, the fabric shows a much lower pilling tendency. Other benefits of removing fuzz are clean, softer, smoother feel, and superior colour brightness. In traditional techniques the surface fuzz is removed by a process called singeing: ie the fabric is passed over a flame with speed to burn the protruding surface fibres.

These cellulases perform a catalytic action on 1, 4-beta-glucosidic linkage of cellulosic molecule, leading to the hydrolysis of the bond into smaller parts which may be further reduced. The combination of enzyme hydrolysis and mechanical action in the machine removes the surface fibres from the material.

Singeing versus bio polishing

Disadvantages of singeing:

- Flame gaps – singe streaks.
- Melt balls – may dye darker.

Advantages of bio-polishing:

English

- Improvement in fabric aesthetics and characteristic.
- Removal of surface fuzz and pills, pilling prevention.
- Elimination of neps and motes.
- Increased luster, brighter colour.
- Improved surface appearance.
- These benefits are permanent.

Pumice stones versus cellulase

Disadvantages of pumice stone:

- Loss of strength of the fabric.
- Accumulation of large amounts of sludge together with fibre residues and indigo pigments, which had to be disposed of.
- Unloading the machine after stone treatment is very difficult because stones and their split-off remainders were all over and had to be removed from the trousers.
- Pumice stones are a natural raw material and their occurrence is limited.

Advantages cellulase enzymes:

- Less loss of strength of the fabric.
- Abrasion-faded look highlighting seams, hems, pockets, etc.
- Imparts softness.
- Good contrast observed.
- No sludge problem.
- Easy handling.

i) Water/oil/stain proofing [2], [21], [52]

- Avoid the use of lead or other metal
- Use N-methylol stearamide fluro chemical type
- Water / Oil / Dust Repellent Aids: Piscean Hydroil Guard Series. Weak cationic, polymeric types. Does not influence fabric colour, softness. Yields durable water, oil, and dirt repellent. Treated fabrics experience smoother hand-feel effects with improved form retention.

5. INNOVATIVE ECO-FRIENDLY WET PROCESSING OF TEXTILE

5.1 Plasma technology in textile processing [54]

What is plasma?

- Highly reactive material is used to modify the surface of the substrate, ie plasma activation or modification.
- It is a substance, usually, a gas whose atoms have one or more electrons detached and hence ionised.
- Overall neutral as it consists of equal no of –ve and +ve ions called plasma.

How plasma is produced?

1) By providing heat to gas (high temperature) or when the kinetic energy of gas particles rises equal to the ionization energy of the gas, eg atmosphere of most stars, gases on the upper atmosphere of earth (about 400 km) gas within the glass tubing of neon advertising signs.

2) To pass high-energy electrons to a low-pressure gas. The individually charged plasma particles can be controlled by an electric or magnetic field.

English

3) By applying an electric field to a low-pressure gas.

Plasma processing

- High-density plasma is not suitable for textile applications.
- Plasma density depends on temperature and the magnetic field applied.

How does plasma work on cotton textiles?

- It is only a surface reaction.
- Modifies the surface in nm range (100nm)
- Coats the fibre with nm thin film, depending on the gas used. This technique can be used to make fibre.
- Hydrophilic properties can be imparted by oxygen plasma.
- Hydrophobic properties can be imparted by hexafloroethane plasma.
- Improves colour fastness.
- Improves dyeing rates.
- Improves shrinkage resistance.
- Reduces inflammability.
- Improves pigment fixation.
- Flouring plasma for medical textiles.
- Facilitates the removal of size and contaminants.

5.2 Ultrasonic assisted wet processing [55]
Frequency name of the range

- <20Hz - Intrasonic range.
- 20HZ to 20KH - Audible range.
- >20KHz (20KHz to 500MHz) - Ultrasonic range.
  Higher frequency will shorten the wavelength.

What is the frequency? It is the number of cycles per second.

What are compression and rarefactions?

- Areas of high and low local pressure, eg ultrasound.
- They give rise to cavities and bubbles.
- They create shock waves.
- The formation of bubble and its collapse is responsible for ultrasonic effect in solid/liquid.

How is ultrasound produced?
By converting electrical energy to mechanical energy.

Textile applications

- Reduces the average size of dye particles.
- Reduces glass transition temperature (Tg).
- Increase the swelling of cellulosic fibres (unmercerised-50%).
- Swelling is retained up to one hour after the removal of ultrasound.
- Use of electricity in place of expensive thermal energy.
- Can be applied in desizing, scouring, bleaching, washing, dyeing, and finishing.
- Trials of use of ultrasonic in cotton dyeing with direct, reactive effect.
- Creates greater evenness.

5.3 Automation in textile
The standardisation of components takes place thanks to the concentration of automation technologies in some basic types of operations (processes) which must be carried out by the machine. The machine is characterised by a system made of inputs and outputs. Inputs are sensors that transform the physical variables of the system into electrical values that can be read and processed by an electronic unit. Outputs are the actuators controlling the machine and consequently the process (motors, solenoid valves, thermoreceptors).

Any process can generally refer to this operating scheme and can be controlled by making inputs operating about the state of the output and following a preset sequence of times. The computer, using the appropriate software, supplies the logical links between inputs and outputs and controls the right process sequence. The main difference between automated systems essentially lies in the number of variables controlled. Following some of the automation in the textile:

- Colour analysis.
- Process control.
- Production control systems.
- Colour kitchen.
- Automated inventory control systems.
- Transport and robotised systems.
- Machine control systems.

5.4 Low liquor / foam finishing technology [35]

- **Foam**
  Foams are microheterogeneous colloidal systems in which gases are distributed within a liquid or solid dispersing agent. When air is passed through a surfactant solution the surfactant is absorbed on the surface of the bubbles to form a film. As the bubbles break through the liquid/air interface, a double film is formed, ie a foam lamella consisting of two monomolecular films of surfactant and the interlamellar liquid. The accumulation and reciprocal contact of the bubbles in the liquid also plays a part in this film formation process. When solutions of substances with low surface activity are used for the generation of foam, eg short-chain alcohols or acids (eg humic acids in wastewaters as direct pollutants in biological wastewater treatment plants), foams are formed which are often only stable for a few seconds. Foams with considerably longer stability are produced with substances that cause a considerable decrease in the surface tension of water (eg soaps, non-ionic, cationic and amphoteric surfactants).
- **Foam application**
  Processes used for the low wet pick-up of concentrated foamed finishing liquors, especially for wash and wear finishes on textile fabrics with a possible pick-up of 40% and mainly 10-20%. Foamed liquors are applied to the textile directly then brought to the desired thickness employing squeeze rollers or a knife coater, eg two-sided foam application in a horizontal two-bowl padder, one-sided application to carpets, foam application with an air-roll squeegee. The following foam properties are required for continuous finishing:

– Uniformly homogeneous foam.

– Variable blow ratio.

– Low foam stability (foam decay half-life period).

– Rapid breakdown of foam on contact with the textile substrate.

The following methods of application of foamed liquors to textile fabrics:

1. The fabric to be foam finished is guided over a roller in such a way that a blade or knife is positioned over the upper crown of the roller and out of contact with the fabric. By this means foamed liquor is fed to the fabric in amounts determined by the height of the gap between the knife edge and the fabric surface.
2. This method can be modified by applying the foamed liquor from a rotary screen in which all the perforations are open
double squeegee.

English

3. Foam can also be applied to carpets through a slotted hopper across the entire width. The foam height is precisely defined by passage through a padder with a pre-set gap between the rollers.
4. Slop padding is also employed as a foam application technique.
5. Finally, foam may be applied between the nip of a horizontal padder.

5.5 One-step process for desizing, scouring, bleaching and mercerizing cotton fabrics [9]
According to Dr N Sekar, the one-step treatment involves the impregnation of cotton in a mixture of sodium hydroxide, hydrogen peroxide, and trichlororoethylene each at a particular concentration.

However, in this study, it has been concluded as follows:

- At low dipping temperature, the one-step of cotton fabrics enhanced strength retention and colour strengths are achieved.
- High-temperature treatments enhance whiteness, stiffness and wettability.

5.6 Two-step processes [4]

- Combining the desizing and scouring and separately bleaching processes can save water, chemicals, energy and reduce processing time.
- Combining the scouring and bleaching and separately desizing processes can save water, chemicals, energy and reduce processing time.

5.7 Replacement of acetic acid
Replacement of acetic acid (used for pH adjustment or neutralizing of the bath) with formic or green acids to reduce effluent load.

5.8 Adaptation of optimisation in wet processes
The optimum amounts of chemicals or auxiliaries are used in all processes that depend on the raw material for the process.

5.9 Electrochemical mercerization, souring, and bleaching of textiles
Economical, pollution-free treatment of textiles occurs in a low voltage electrochemical cell that mercerises (or scours), sours and optionally bleaches without effluents and the purchase of bulk caustic, neutralising acids, or bleaches. The cell produces a base in the cathodic chamber for mercerisation and an equivalent amount of acid in the anodic chamber for neutralising the fabric. Gas diffusion electrodes are used for one or both electrodes and may simultaneously generate hydrogen peroxide for bleaching. The preferred configuration is a stack of bipolar electrodes, in which one or both of the anode and cathode are gas diffusion electrodes, and where no hydrogen gas is evolved at the cathode.

6. SUMMARY

Being the chief cause of pollution, the textile wet processing industry needs to be looked at carefully from an ecological point of view. Eco-substitutes for these chemicals will not only help the consumer but also society, which is directly affected by it. Also, workers' safety needs to be closely looked at, since they are the first to be affected by any immediate exposure. Some substitutes are even better and economical than their precursors. Hence use of such products should not be delayed. From an environmental and ecological point of view, enzymes also serve as substitutes, especially for the preparatory process. The motto of the textile process should then be, "Substitution is better than cure."

The worldwide consumption of cotton is going to increase due to its properties of comfort, cost-effectiveness, and environmental friendliness. The textile industry also faces the problem of effluent and waste disposal. Also, the red-listed chemicals and banned dyes are carcinogenic and/or highly toxic. It is the number of contaminants present in the final product that causes harmful effects on the human body. On the other hand, with increasing awareness of the environment, regulations are becoming stricter day-by-day the world over.

We have polluted our environment over the last 150 years. It’s time to take steps to save our planet Earth and make regulations and laws to strictly enforce the same, or else like J. Krishnamurthy says, “Our present is because of what we were in the past and our future is what we are in the present.” Change now or there is no way mankind will be saved. We are doomed to extinction.

English

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