Environment-friendly processing of protein fibres

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The various practical and theoretical approaches adopted during the last decade towards the environment-friendly chemical processing of wool and silk are highlighted. The ways and means are available at the disposal of a chemical processor to evolve an ecofriendly wool/silk product, even with desired value addition. However, certain processes like ultrasound and plasma treatment need to be explored at the bulk processing level.

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1 Introduction  

Environmental issues have so far never received the importance they should have, although the industry always seemed to be aware of it. It is the quest of common man in last about two decades that these issues have come to the surface and are being addressed to with greater concern. The environmental pollution has long since ceased to be the sign of progress, which it was in the earlier part of the 20th century. With increasing industrialization, the pollution and its impact on nature and human culture has crossed limits and hence the seriousness about its abatement.

Chemical processing of textile materials involves the maximum possibilities of polluting chemicals being used. A number of chemicals and dyestuffs, which are being used liberally in order to enhance the so-called quality, contain toxic and hazardous substances. These may be the chlorinated scouring and bleaching chemicals, the banned amine-based dyestuffs, heavy metal traces present in dyestuffs, stain removers, formaldehyde-based dye fixatives, softeners, crosslinking agents, preservatives, etc. These are now known to not only damage the environment, but also to affect the consumer of textile products. From the point of view of being environment friendly, one approach is to switch over to purely mechanical finishes instead of chemical or assisted finishes, but this may not be feasible all the time. In dyeing, the use of natural dyes has been boosted, but with inherent limitations.

Among the various fibres used in the making of textiles, the classification broadly categorizes them into those procured from natural sources directly or indirectly and those fully synthesized from the petroleum products. The latter are more or less non-biodegradable as they are synthetic. However, the former being natural (including cellulosics and animal protein fibres) are fully biodegradable. Hence, it is a minimum expectation of anybody having concern about environmental pollution abatement that at least in the case of natural fibres, the use of polluting chemicals should be avoided as far as possible.

With such an approach, the thinking has given rise to the principles of pollution abatement as:

- Use minimum to start so that less is wasted and, therefore, will cause least discharge to the environment.
- Reuse and recycle the products wherever possible so that their useful life is enhanced and the period to discard them to environment is delayed.
- Change, replace or redesign the processes in order to be more environment friendly by use of ecofriendly chemicals, energy conserving routes, etc.

Among the different natural textile fibres in use today, wool and silk are the two high priced protein fibres known to mankind for ages.

Silk is a smooth, lustrous and elastic filament of small diameter, which is obtained from the cocoons of the silk worm. When unwound from cocoons, silk is obtained as a continuous filament. It combines strength with lightness, durability with beauty and
cleanliness with lustre. Silk is the most beautiful continuous filament and the fabrics made out of it have exceptionally pleasing lustre, soft handle and comfort.

Wool possesses unique physical and chemical properties. Its bilateral structure causes crimpiness to the hair, giving rise to a large number of air pockets, which are capable of retaining warmth. Its draping qualities are outstanding due to its high extensibility. It absorbs a large amount of moisture, leading to comfort. The general chemical process sequence for wool consists of carbonising, scouring and bleaching, dyeing and finishing.

2 Processing of Silk

Silk is mainly composed of fibroin — the textile filament — and sericin, the outer gummy matter adhering to the filament and comprising of 20-25% of the total mass.

The main chemical process sequence for silk, in general, includes degumming, bleaching, dyeing and finishing.

2.1 Degumming of Silk

Main impurities in silk are sericin, lubricants and softeners (added during throwing or during preparation for weaving/knitting), dirt and oil picked up incidentally during processing and the undesirable colouring matter. Removal of sericin (degumming) is essential so as to make the silk material soft and supple with requisite lustre. It needs to be removed uniformly otherwise it gives non-uniform results. This sericin is removed to various degrees and gives rise to different commercial varieties of silk such as ecru, souple and cuit each with increasing level of degumming.

Essentially, degumming of silk is hydrolysis of protein sericin and it may be carried out conventionally by acids or alkalies. Normally, the chemicals used in degumming are not harsh on environment as they comprise weak alkali, soap, etc. Non-ionic detergents are preferred over soap due to their better efficiency under neutral conditions, stability to hard water, lower cost and more efficient cleaning. However, from the point of view of better results in terms of appearance and feel of the degummed silk filament, the use of enzymes is gaining importance.

The proteolytic enzymes are soft on fibre and they hydrolyse the peptide bonds formed by amino acids in silk. The varieties available are trypsin, papain and bacterial enzymes. Trypsin is a serine protease, active at room temperature and pH 7 - 9. Sericin is a polar and less crystalline protein with high lysine and arginine content, which can easily get hydrolysed by trypsin. On the other hand, the fibroin, being less polar, highly crystalline and low in lysine and arginine, is not affected by this enzyme. Another enzyme papain is sulphhydril enzyme, active at 70-90°C and pH 5 - 7.5, whereas the bacterial enzyme alcalase is active at 60°C at pH 9.

Gulrajani et al.² have shown that degummmase improves the wettability and whiteness of the silk fabric without affecting its strength.

Gulrajani and Gupta³ carried out enzymatic processing of waste silk fabric. Such fabrics have good drape and durability for upholstery and furnishings. Spun silk used in such fabrics contains many impurities including cellulosic ones. By use of the cellulase enzyme from Trichoderma reesei along with a proteolytic enzyme degummmase 100L, they obtained complete removal of impurities, at the same time improving the wettability.

2.2 Bleaching of Silk

Although the naturally present colours in different silk varieties are the most desired ones, sometimes there is a demand for white material or it becomes a necessity for getting pure shades. In such cases, bleaching is essential and it is carried out using either reducing or oxidising bleaching agents. Among the different oxidising agents, hydrogen peroxide has been shown to be the best bleaching agent for mulberry and tasser silk varieties from the point of view of better whiteness and lower loss in moisture regain and tensile strength. Among various types of bleaches, this is the only ecofriendly bleaching agent.

2.3 Dyeing of Silk

Silk can be dyed conventionally using acid, metal complex, basic and direct dyes. Other than in case of metal complex dyes, the wet fastness of dyed silk is unsatisfactory. From environmental safety point of view, it is essential to select the dyestuffs based on various criteria. The very first is to opt for the dyestuffs which are not based on any of the twenty banned amines as per the guidelines of German Ban. Most of such dyes belong to direct and acid application classes of dyes, hence the caution. Once these are thrashed out, among the remaining ones, and
this applied to all the dyeings, the selection should be based on high exhaustion of dyes on the fibres as far as possible. This precaution will tend to let out only a limited amount of dye into the effluent discharge, which requires further treatment for pollution control. Any amount of dye discharged into effluent increases the BOD, COD load as well as the unpleasing appearance to water streams and hence, little is better.

Lewis and Shaoo used sulphatoethyl sulphone type (Remazol by Hoechst) reactive dyes for dyeing silk to obtain high brilliancy and better wet fastness properties. These dyes can be applied at pH 7 - 8 and 80°C in the presence of 30 -50 g/l salt. They improved the dye exhaustion considerably, thereby eliminating the use of salt for exhaustion. The degree of fixation was also enhanced. The process called β-elimination to yield vinyl sulphone dye with least hydrolysis was optimised at pH 7 for 10 min at 100°C, followed by dyeing at pH 4 - 4.5 using buffer system.

An attempt was made to dye silk with cationic, acid and metal complex dyes at low temperature in the presence of ultrasonic energy for relatively short durations. When the results were compared with those of the conventional dyeing processes which are carried out at higher temperature and for longer dyeing times, it was found that the ultrasonic energy could give good fast dyeings, many times comparable with the conventional dye uptakes. The process is energy efficient since it conserves energy as well as time. In another attempt, certain selected dyes of direct and acid classes were dyed under the weak ultraviolet radiations in the presence of UV radiations and a photo initiator. Not all dyes, but only those, which could form free radicals, could respond to this energy conserving process of dyeing.

3 Processing of Wool
Wool, another important protein hair fibre, is covered by the outer cuticular layer or the scales. Although the function of these scales is to protect the hair from weather, abrasion, etc., it is the main hindrance during efficient and uniform chemical processing of wool. The scales offer hydrophobicity, decreased absorbance to dyes and chemicals, felting tendency in aqueous baths, non-easy care properties and harsh feel. Complete removal of the scales is detrimental to the fibre properties. However, partial and uniform removal is essential for getting better out of the wool characteristics. Earlier non-ecofriendly method was to make use of chlorination. The wool grease obtained after scouring process is of great value and hence, it is always advisable to recover it. Cabonisation of wool removes the cellulosic and allied impurities from wool material by acid treatment.

Wool has been used to produce floor coverings since time immemorial and recently there has been a revival in the popularity of wool for carpets and rugs. The unique molecular structure of wool gives it advantages over other fibres. The use of woolen carpets in an interior environment can reduce allergenic and harmful substances such as nitrous oxide and formaldehyde. Wool is “green” being a renewable resource and biodegradable. Being naturally resistant to dirt, wool does not require the use of anti-soiling agents and has a reduced requirement for cleaning substances. Wool is extremely durable but is susceptible to moth damage.

It was observed by Shaw that organochlorine pesticides in contaminated raw wool are not completely removed by the scouring process and may pollute processing effluents.

Wooltech Group, Italy, has developed a non-aqueous wool scouring and processing system. It uses no water and, therefore, leaves behind no effluent or unwanted waste. It cleans without entanglement, increases tensile strength of the fibres, and is capable of producing cleaned wool that can be successfully spun on the rotor system. It makes use of ICI’s Triwool solvent as the cleaning agent, being non-flammable and non-carcinogenic with no depletion of the ozone or production of greenhouse gas.

Enzymes have begun to assume increasing importance in textile finishing. One of the main
reasons for this wider application of enzymes has been the steady increase in environmental awareness on the part of consumers as well as the legislations regarding the environmental protection. The substrate specific reactions of enzymes offer the possibility to control a chemical reaction in such a way that no undesirable side reactions take place.

Enzymes are biocatalysts. Catalysts participate in a chemical or biochemical reaction in such a manner that they emerge from it unchanged at the end of the reaction. Enzyme action is specific and they will only participate in very individual reactions or substrates. Because of their complex composition, the enzymatic reactions of protein fibres are extremely varied.

Proteases are multi-enzymatic systems, which catalyse the hydrolytic degradation of protein fibres. Proteinase splits the large molecular protein molecules to polypeptide chains or individual polypeptides. Endopeptidase hydrolysates the peptide bond both at the end of the molecule as well as inside the molecule, whereas exopeptidase exclusively breaks down the chain ends.

Ying and Tian observed that the addition of enzyme to the scouring bath considerably enhances the scouring effect for wool. The optimal scouring conditions were: enzyme concentration 0.015-0.02%, temperature 55°C, pH 10-11, and (NH₄)₂SO₄ or Na₂CO₃ as auxiliary agent.

Enzyme treatment of the fibre considerably improved dyeability due to degradation of the hydrophobic barrier by the lipoprotein lipases. As a result, the accessibility of the fibre to the aqueous dye liquor increased. Moreover, the degradation of proteins within the fibre allowed greater accessibility and mobility for the dye molecules. Even a mild enzyme treatment of wool markedly improves dyeability without causing significant fibre damage.

A novel cuticle-degrading enzyme for degrading cuticle on the surface of animal hair is prepared from the culture of Bacillus cereus strain NS-1. The enzyme is useful in processing animal hair fibres like wool to improve their quality by increasing water absorbancy, decreasing static property, decreasing shrinkage, etc. The enzyme exhibits a pH optimum 8 and temperature optimum 45°C.

Another enzyme, Proteinase-NH is isolated from the culture of Aeromonas hydrophila strain and it is able to hydrolyse water-insoluble protein keratin during processing of wool. The enzyme exhibits a pH optimum 7-9 and temperature optimum 50-60°C.

The use of low-pressure/low-temperature plasma for pretreating wool is shown by Fuchs and Hocker to offer small and medium sized companies an ecofriendly acceptable and economically optimum way to dye the material. The wool, however, has a somewhat harsher handle and rougher surface as a result. This is due to the removal of fats. Dyeing behaviour is much improved and effluent is reduced. Colour fastness is better and dye fixing times are reduced.

3.1 Bleaching of Wool

The two-stage bleaching for wool is unsurpassed in its bleaching effect but new bleaching agents and processes permit more rapid, more economical and less environment-damaging bleaching. Reincke described acid quick bleaching with hydrogen peroxide in continuous and discontinuous application as well as optimised reductive bleaching with hydrosulphite. New developments Blankit AN and AR have been presented.

Cegarra et al. investigated environmental properties of different stabilizers for wool bleaching with hydrogen peroxide. Alkaline phosphates are not being used in modern textile scouring and bleaching operations because of their adverse environmental effects. They used three different stabilizers, namely sodium nitritotriacetate, sodium diethylene triaminpentamethyl phosphonate and a mixture of sodium pyrophosphate + ammonium oxalate. The last one is usually recommended for peroxide bleaching of wool. The P content of the mixed stabilizer was found to decrease to 57% of the initial quantity in the effluent, which is concentrated one. Also, the eutrophication values were within the range. Thus, the mixed stabilizer was found to be more useful, at the same time being environment friendly.

The whiteness obtained in wool bleaching was found to enhance by the presence of protease, with both peroxide bleaching and when sodium dithionate or bisulphite was used. However, the increased whiteness is accompanied by the loss in both weight and strength.

The effect of enzyme treatment on whiteness, dyeability and other properties of wool tops and wool fabrics have been investigated by Schumacher et al. It is shown that protease treatment improves the
whiteness as well as dyeability with Lanasol Reactive Dyes.

3.2 Dyeing of Wool

Seventy per cent of dyes used for wool either contain heavy metals like chromium or require chromium for their applications. About 30% of this total utilizes traditional afterchrome method using dichromate anions added to exhausted dye bath or separately in fresh bath.

Afterchrome dyes are widely used for wool dyeing since they are economically attractive, have outstanding wet fastness and provide full shades. The main disadvantage is the left out chromium in the effluent. Generally, it should be 1mg/L remaining in the exhausted dye bath. Chroming is usually carried out by aftertreating the chelatable dye with dichromate. Optimum pH conditions under which divalent dichromate anion exhausts on wool are essential to determine, since these will reduce residual chromium in the dye bath.

According to Thomas et al., after the reduction of chromium-VI to chromium-III, 1:1 and 1:2 complexes are formed in fibre. In the exhausted bath, both chromium-VI and chromium-III exist. Chromium-III takes part in glucose metabolism of human organism and therefore essential. Chromium-VI is most toxic, toxicity being related to its oxidation potential. It easily penetrates cell membranes and oxidises cell components. It is also absorbed by skin and respiratory tract. Two mg/L total chromium and 0.5mg/L of chromium-VI are permitted at individual process stage, but not in the completely diluted effluent. Complexing agents and salts inhibit extraction of chromium and, therefore, need to be eliminated from the bath.

Maximum exhaustion of dichromate occurs below pH 3.5 due to its high affinity to protonated NH₄ of wool. Reduction of chromium-VI to chromium-III occurs fairly rapidly within the fibre and it is accompanied by oxidation of cystine disulphide linkages. Under strong acidic conditions, chromium-III will be repelled by protonated amino groups and if pH is low, then chromium-III will even be desorbed.

Houlton has reviewed the methods which are being applied to wool dyeing to reduce chromium levels in the effluent. In metal complex dyes, heavy metal is precomplexed with a dye chromophore by the manufacturer. It is mostly chromium, but cobalt also is used to form 1:1 or 1:2 metal complex dyes. The 1:1 metal complex dyes are first developed and these are applied from strongly acidic bath. These are mainly used for dyeing of piece goods where good migration properties are essential for level dyeing. The 1:2 metal complex dyes give greater wet fastness and are applied under less acidic conditions. These are mainly used for dyeing of tops, loose wool and yarn.

The levels for chromium in effluent from traditional chromium dyeing are 20-150 mg/L. Optimised conditions for dyeing can reduce them substantially. Thus, for 1:1 and 1:2 metal complex dyes, the chromium levels can be reduced to 3-13 mg/L and < 7mg/L respectively. Modified dyeing processes help in this regard.

There are several parameter in chrome dyeing which, when optimized, can reduce chromium residues.

The addition of dichromate must be minimised in accordance with the dyestuff manufacturers recommendations, since reduced chromium additions will lead to lower residual levels.

If the dye bath exhaustion is incomplete before chroming, then residual dye in the liquor will be chromed and remain in the liquor to add to the discharged chromium. Optimum results are obtained by chroming in a fresh bath or by increasing dye bath exhaustion.

There is an optimum pH region (3.5 - 3.8) to be attained with formic acid for ensuring maximum efficiency of chroming and, therefore, minimum residual chromium levels. Other acids may reduce the efficiency of chroming.

It is also essential, for maximum chroming efficiency, to eliminate chemicals from the chroming bath which will inhibit the chromium-dye interaction, such as sequestering agents. Sulphate ions also inhibit the exhaustion of the dichromate anion and should also be omitted from chrome dye baths.

A range of optimised chroming methods are available to minimise the chromium residues in dyehouse effluent from chrome dyeing. Techniques have been developed by IWS, Bayer, Ciba – Geigy and Sandoz.

The Bayer technique as well as Sandoz method uses minimum dichromate levels, calculated from their own published chrome factors for each dyestuff, and the addition of sodium sulphate or Lyocol CR
respectively to the chroming bath to aid level chroming when using the minimum dichromate levels.

The IWS low-temperature (90°C) chrome dyeing method uses sodium thiosulphate in chroming, and offers the advantages of reduced fibre damage and energy savings as well as reduced levels of chromium in the effluent. In application of 1:1 metal complex, high acidity (8% \( \text{H}_2\text{SO}_4 \)) is used to promote migration and, therefore, levelness. Increasing migration reduces exhaustion of chromium and, therefore, high levels of residual chromium in the bath. Ciba has developed modified 1:1 complexes (Neolan P) which are applied at pH 3.5-4 but along with specific auxiliary which promotes dye bath exhaustion, reduces fibre damage and increases shade reproducibility. Another way is using sulphamic acid in place of \( \text{H}_2\text{SO}_4 \) (BASF). This slowly decomposes in hot dye bath and increases pH to reduce acidity. The initial pH 2.0-2.5 in combination with a specific auxiliary ensures good migration whilst the increase to pH 3.0-3.5 as the dye bath temperature increases, gives good exhaustion.

Xing and Pailthorpe controlled the pH of dye bath at < 3.5 for 2 min before dichromate was added and then at > 3.5 after most reduction of dichromate had taken place. Sulphamic acid was used for this purpose. It can react with primary amino groups of wool and also, it hydrolyses at boil, thereby increasing the dye bath pH gradually and significantly in chroming stage. The chromium-VI and chromium-III residues can be reduced either separately or simultaneously without damaging wool. They further found that the rare earth cations can complex with the chrome dyes to form coordination compounds. The coordination compounds formed in this way are not stable and the rare earth cations are replaced by trivalent chromium ions in the afterchroming stage. This ion exchange process allows time for chromium ions to migrate on wool substrate and hence level chroming is achieved in spite of low level of dichromate addition. The reduction in exhausted bath was significant without any adverse effects to wool or colour.

In an article on improvements in wool dyeing, Bide stated that the environmental pressures on the mordant dyeing led to the development of a number of methods of low-chromium dyeing. All these methods involve close control of the level of chromium applied, and of pH during dyeing and chroming. In various ways, the methods ensure that most of the chromium is converted from chromium-VI to chromium-III and this is complexed by wool rather than discharged with dye bath.

Acid dosing systems for 1:2 metal complex dyes also reduce fibre damage and speed up dyeing process. Removal of chromium from the bath gives problem of chromium containing sludge. Ciba has developed a new reactive black for wool, which does not contain any metal and has very high fastness equivalent to chrome dyes.

Sokolowska et al. synthesized 1:2 iron complexed azo dyes and compared their properties with 1:2 chromium and 1:2 cobalt commercial analogs. They found that the new black dyes are very good for wool and nylon from the light and rubbing fastness point of view, at the same time they are ecofriendly.

Julia et al. made use of aluminium as an alternative to chromium and optimised the dyeing conditions to obtain maximum fastness levels for the chrome dyes on wool.

Schuh and Wolf developed an environment-friendly method for dyeing wool in black shades and hence to avoid afterchroming. It was found that the use of porphyrazines enables this to be done.

Rao et al. are of the opinion that it is desirable to replace chrome mordanting in application in anticipation of a total ban on chromium in industrial effluents and a viable alternative method of mordanting has to be thought of. In the decentralised sector of Indian industry, natural dyeing has scope for exploitation.

Ahmed et al. carried out the dyeing of the natural dyes kamala, indigo, turmeric and henna on mulberry silk. It was found that the general appearance, lustre and texture of kamala dyed silk fabric was better than that of other dyed samples.

Most natural dyes are less stable to light when compared to the best synthetic dyes. Gupta has tabulated the light fastness ratings of several common Indian natural dyes on wool.

The use of dyes derived from vegetable and animal raw materials has been discussed in a review. The benefits of using natural dye with respect to energy usage, water consumption, biodegradability and allergenic effects are presented together with
3.3 Finishing of Wool

In the textile industry, the manufacture of non-shrinkable wool is the most important process since this type of wool allows hand and machine washing, without the garments being damaged by felting shrinkage. Numerous procedures are followed for making wool non-shrinkable. Some of these procedures may present problems from an ecological point of view.

The availability of an anti-felting treatment compatible with ecology is nowadays a most desirable objective. Wool treatment with enzymes could be one of these systems. The enzymatic application on wool to make it non-shrinkable has been studied for a long time and yet the practical results have not been industrially successful.

The main problem with this enzymatic process is that a distinct change in wool handle occurs due to intensive action of the proteases needed to break down the layer of scales chiefly responsible for wool felting. Moreover, the process also causes a loss in strength of the wool since enzyme action within the fibres also takes place during this intensive action.

The achievement of different variations in handle through changes in the surface of wool fabrics by enzymatic processes has now become a reality. In this way, cashmere like handle can be produced on a relatively smooth and flat woven wool fabric by enzyme treatment. Such enzyme treatments are also suitable for finishing cheap wool qualities.

Riva et al.\textsuperscript{36} worked on shrinkproofing of wool using a proteolytic enzyme, derived from the bacterium \textit{Streptomyces Fradiae Protease}(SFP), capable of attacking natural keratin and hydrolysing some peptide linkages. They found that the shrinkage reduced even at low enzyme concentration and the effect increased with increasing concentration and time.

Details are given of an enzymatic method for the anti-felting finishing of wool\textsuperscript{37}. Anti-felting finishing of wool can be carried out on current machines in the textile finishing industry and the method is environment friendly as no chlorine is involved. The natural characteristics of wool are retained and whiteness, pilling behaviour and dyeability are improved.

McDerritt and Winkler\textsuperscript{38} described a method for treating wool with a proteolytic enzyme and a transglutaminase. The method results in improved shrink resistance, handle, appearance, wettability, reduction of felting tendency, increased whiteness, reduction of pilling, improved softness, etc. Further, the method also results in reduced weight loss, reduced fibre damage and improved strength.

Aulbach\textsuperscript{39} described an enzyme process for anti-felting treatment of wool tops.

Nolte \textit{et al.}\textsuperscript{40} studied the enzymatic (proteolytic and lipolytic) treatments on wool (untreated and shrink-resist treated) material from easy care point of view and found that such treatments have high potential in substituting normal processes in order to save environmental hazards of processing and that the treatments are useful in providing a range of benefits to wool such as reduced felting and pilling propensity, improved softness and low-temperature dyeability.

3.4 Plasma Treatment of Wool

Ecological and economic restrictions, which are increasingly imposed on the textile industry, require the development of environment-friendly and economic processes. Effluents originating from wool processing get polluted with a variety of substances e.g. chloro-organic compounds from antifelt finishing and dyeing processes or heavy metals from dyeing.

In wool finishing processes such as printing, dyeing and anti-felting finishing, surface morphology plays an important role. The required surface modification is mainly accomplished by wet chemical processes. An appropriate alternative to the conventional techniques is given by the aftertreatment of wool with low-temperature glow discharges.

A number of investigations on the effect of plasma treatment on wool have shown that it leads to improvement in the mechanical properties of the fibre and also improves the dyeability with acid dyes and reduces the felting tendency. This is due to a surface specific modification of wool by the plasma pretreatment. On treating wool fibres with different plasma gases, the extent of hydrophilic groups increases and part of cystine in the surface layer is converted to cysteic acid. The density of crosslinks in the surface layer of wool decreases by the reactive species in the plasma gas and this increases the dye uptake. Also, the
endocuticle and the interscale cell membrane complex are modified to facilitate the diffusion of the dye.

The internal lipids of the cell membrane complex are modified to a certain extent. These changes in the fibre interior are caused by short range ultraviolet radiation which is produced by the low-temperature glow discharge plasma apart from the chemical active species such as electrons, radicals, etc. Hocker et al.41 observed improved acid, chrome and reactive dye uptake at shorter boiling times with excellent fastness levels on dyeing of glow discharge-treated wool for only 20 min. Also, the method was found useful to enhance chromium uptake, thereby reducing the levels of chromium discharged in the effluent. The plasma treatment leads to a higher degree of reactive dye fixation. Thus, the quality of the effluent from reactive dyeing can be improved by pretreating wool with gas discharges. No AOX was detected in the effluent of the ammonia aftertreatment bath.

3.5 Wool Effluent—Reuse and Recycle

Waste water from wool processing in carpet manufacture is treated for recycling after screening, sand filtration, microfiltration, coagulation with Al$_2$(SO$_4$)$_3$, adsorption on coal, second coagulation and heating to 60-80°C for COD, surfactant, suspended solids, and turbidity removal with efficiency >90% (ref. 42).

The key to wool scouring waste water disposal is the recovery of the wool grease to the greatest extent. A new technique, centrifugal extraction, used for grease recovery has been introduced by Liu and Li43. Centrifugal extractor was used as the main separator and hexane was used as the extractor solvent. It is claimed that the technique is especially suitable for scouring the lower grease content effluent.

The system for dyeing of wool called Sirolan Low Temperature Dyeing offers energy savings and reduces the quantity of unused dyestuffs and chemicals discharged44. The wool scour waste treatment system Sirolan- CF removes 95% of wool wax and 99% of soil from waste water.

The Environ Proof System from Petric Group Ltd.45 is designed to minimise effluent contamination in moth-proofing carpet yarn. It reduces manual handling of the chemical, uses automated liquor preparation and computer monitor application.

Keratinic polypeptides were prepared from wool lint waste by treatment with acids or alkalis at elevated pressure and temperature in the presence of catalysts46. These were reacted with fatty acids, acrylic acid or butadiene derivatives and used as protective coatings for wool in dyeing, washing, bleaching and fixing. The quality of wool was improved.

Proteins and protein hydrolyzates as well as modified proteins could be used as textile finishing agents, thus providing a new field of application for protein waste products. These were applied to wool top and fabrics under bleaching and dyeing conditions and their effect on the sorption of the wool fibres as well as their effectiveness as fibre protective agents was studied by Schaefer47.

Dextran-immobilized Proteinase K was found more active than Proteinase K at pH 8 and 50°C. By limiting the enzyme reaction to the wool fibre surface, the immobilization of the enzyme made it possible to recycle it after an initial period on the wool and offered technical as well as ecological and economical advantages in the processing of wool top48.

4 Remarks

The ways and means are available at the disposal of a chemical processor to evolve an ecofriendly wool/silk product, even with desired value addition. However, certain processes like ultrasound and plasma treatment need to be explored at the bulk processing level.

References