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Recent advances in chemical processing of natural and synthetic textiles

Aaditaa Singh, Shahnaz Jahan and Shefali Massey

Aaditaa Singh
Ph.D Research Scholar, Department of Clothing and Textiles, College of Home Science, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

Shahnaz Jahan
Professor, Department of Clothing and Textiles, College of Home Science, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

Shefali Massey
Assistant Professor, Department of Clothing and Textiles, College of Home Science, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

Correspondence
Aaditaa Singh
Ph.D Research Scholar, Department of Clothing and Textiles, College of Home Science, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

Abstract
In the recent years textile industries has witnessed breakthrough inventions in all related fields. Chemical processing sector is also one such field which is influenced by globalization, automation and applications of electronics and information technology. The present review highlights the major changes and advancement in the chemical processing of textile sector. This paper give a brief view of major developments in textile chemical processing, technologies used in processing of natural and synthetic fibres along with their advantages, so that the researchers and industrialists will get to know the future trend in processing sector for textiles.

Keywords: Chemical processing, Desizing, Enzymes, Nanotechnology, Ozone, Plasma

Introduction
Chemical processing of textiles includes removal of natural impurities from textile materials in order to improve its properties and to increase operating efficiencies of textile materials for varied use in other textile operations. The most important step in textile production is textile wet processing which imparts value addition in textiles through improvement in aesthetics, comfort and functional properties (Saxena *et al*., 2017) [13]. The textile wet processing is used for conversion of raw products into clearly discriminated high quality products by the consumers. Thus, textile wet processing is considered as the subsector of chemical processing and it acts as a link between the processes involved in converting grey fabrics into finished fabrics as per the requirements of the market for design and fashion.

The textile wet processing sector requires very large manpower, huge amount of water for generation of steam which act as fuel, dyes and chemicals and proper drainage system in comparison to other sectors of textile industries. There are several pre treatment processes which are applied during textile wet processing. They are desizing, scouring, bleaching, and mercerizing for proper removal of unwanted material so that the affinity for dyeing, printing and finishing treatments could be improved.

Major Developments in Chemical Processing of Textiles
Plasma Technology
A new technology which is used by textile industry at a very large scale is plasma treatment. This technique is used for inducing surface modifications and bulk property enhancements of textile materials which results in improved textile products ranging from conventional fabrics to advanced composites. Plasma is a gaseous medium which can be made by using oxygen, argon, fluorine, helium, carbon dioxide or their mixtures (Kutlu and Cireli, 2016). The basic principle behind working of plasma treatment is modification of uppermost atomic layer of material surface with having any effect on the bulk characteristics. This treatment gives desirable surface modifications, including but not limited to surface etching, surface activation, crosslinking, chain scission, decrystallization, and oxidation. The factors affecting in plasma treatment are type of gas used, plasma density and energy.

Plasma treated products shows a greater affinity which not only increase the dyeing rates of polymers but also improve color fastness with high wash resistance of fabrics, and also change the surface energy of fibers and fabrics. Many researches have shown that plasma treatment given to thermoplastic fibers improve their physical properties such as toughness, tenacity, and shrink resistance (Fibretofashion.com, 2018).

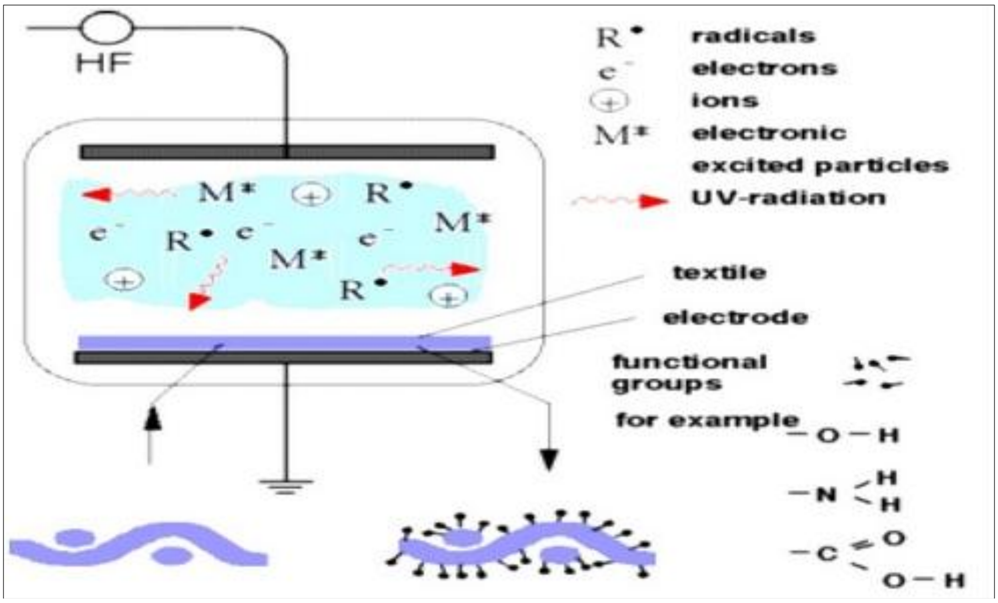

Fig 1: Plasma Treatment of Textiles (Yousefi, *et al*., 2003)

Plasma treatment could be a good alternative of chemical fabric treatment and pretreatment processes which are used in treatment of textile fabrics and yarns.

Waterless Dyeing

The waterless dyeing technology utilizes reclaimed CO_2 as a dye medium. This technology do not uses water and harmful chemicals for dyeing. Closed loop process is used for the conversion of CO_2 into supercritical state. The closed loop process is patented by Dutch company Dyecoo. In this process CO_2 is pressurized and converted into supercritical state which is a state which lies somewhere in between liquid and solid state. The main reason behind conversion of CO_2 into supercritical state is that it has high solvent power which allows dye to dissolve very easily. Two American enterprises namely ColorZen and AirDye have also patented waterless dyeing technique.

According to Yale Environment 360, 2014 this method provides various advantages like zero water consumption, reduced use of chemicals, low energy consumption due to short batch cycles and elimination of waste water treatment process. As CO_2 is an inexhaustible resource, it could be recovered and reused repeatedly making waterless dyeing very economic. The method is sustainable and safe because of the physiological compatibility of CO_2 due to its properties like non- flammability, non- toxic and non- corrosive.

Ultrasonic Textile Processing

In this process frequency is the main factor which is used as an energy source for operating equipments and accelerating rate of chemical reactions in solid, liquid and gaseous mediums. The frequency greater than 20,000 MHz (beyond human hearing) is used in ultrasonic textile processing. This ultrasonic energy in textiles wet processing used during dyeing process enhances the diffusion of dye inside the fibre very efficiently and smoothly (Nagaje and Hulle, 2015) [9].

This technique is also applied in various other processes of textile industries such as scouring of wool, enzymatic bioprocessing of cotton etc. According to Juarez, J. 2012, ultrasonic energy could be utilized in textile washing. However, no significant developments could be achieved till now in ultrasonic textile washing.

Ozone Assisted Textile Processing

Ozone is a gas which is characterized by its blue color. The chemical formula of ozone is O_3 i.e. trioxygen. It is widely used in textile wet processing for bleaching of textile materials. Although, ozone is first used as a bleaching agent in paper industry but now it has been used as a bleaching agent for different type of fibres such as cotton, jute, nylon and silk. Ozone can be converted back to oxygen because it is thermodynamically unstable. Another use of ozone in textile field is in wastewater treatment of textile dye effluent. According to Guendy, 2007 [3], ozone is a strong oxidizing agent and is capable to remove colour completely from effluent.

Nanotechnology Application in Textiles

Nanotechnology is a branch of science which deals with application of new techniques using materials ranging length from 1 to 100 nm. This technology can be introduced to textile materials at two stages, first at fibre and yarn stage during extrusion process and secondly during finishing stage using coating method. The technology is used to impart characteristics to the textile materials like increased tensile strength, water repellency, antimicrobial properties, superior durability and improvement in surface structure, colour fastness and breathability of fabric. (Sawhney *et al*, 2008) [12].

Latest Technologies in Chemical Processing of Natural Textile Material

Natural textile materials are those which are acquired from plants, animals and insects. Some of the well known natural fibres are cotton, wool, silk, linen, nettle, hemp etc. To improve functionality of these natural fibres to be utilized for textiles material, they go through various chemical processing steps such as desizing, scouring, bleaching, mercerization. The use of high amount of chemicals in the processing of these fibres makes them no more natural. Latest technologies in textile processing are focusing on the reduction of use of chemicals, water and making the process faster to meet the ease of growing demands. Some such recent technologies are discussed.

Desizing by using plasma treatment

Desizing is the process by which sizing material such as starch, PVA is removed from the textile materials prior to subsequent processes such as dyeing and finishing. Conventionally, desizing is done in hot water by using oxidative and acid desizing agents. Recently, plasma treatment is found to be effective for desizing textile materials.

According to Textile chemistry, 2014 the process of plasma treatment on sized cotton textile involves treatment at 100-200w oxygen plasma for 8-10 min. This process involves conversion of organic sized materials directly into gaseous phase without involving liquid phase which leads to direct evacuation. After this rinsing with water has to be done which removes about 30-35% of left out sizing material. The disadvantage associated with this process is sized material could not be recovered which otherwise recovered in the conventional process. Kan *et al*, 2014 [5] utilizes the atmospheric pressure plasma for desizing, scouring and bleaching of cotton fabric. The results show that plasma treated cotton fabrics shows higher wettability then conventionally treated cotton fabric.

Bioprocessing- Use of Enzymes for Processing of Textiles

Bioscouring also known as enzymatic scours which involves the removal of impurities from textile materials by using enzymes like pectinase, arylesterase, xylanases, cellulases, laccases and ligninases. Enzymes are bioactive catalysts that can be easily obtained from wastes of juice manufacturing industries and from plant tissues. During the scouring process various chemicals such as sodium hydroxide, sodium bicarbonate are used which increases the pollution load. The use of enzymes helps in removing such toxic chemicals and reduces the pollution load.

According to Teli *et al* 2016 [16], his findings stated that as compared to conventional scouring there is very low amount of strength loss in cotton fabric during bioscouring process. Therefore, this technique gives advantage of reduced strength loss, no usage of chemicals, energy saving, time saving, reduced effluent treatment cost which makes the bioscouring advantageous in terms of quality, environment and economic perspectives.

Nisha, 2016 [10] used pectinase enzyme derived from *Paecilomyces variotii* fungus for bioscouring of cotton fabric. Pectinase enzyme is widely used in beverage industries for clarification of wine, juices and for fermentation of tea, coffee. Other uses include wastewater treatment, vegetable oil extraction, paper bleaching and additive in poultry feed.

Each and every enzyme shows maximum activity at particular temperature, enzyme concentration and time duration. Nisha, 2016 [10] concluded in her result that the bioscouring of cotton fabric using pectinase enzyme showed maximum enzyme activity at 40 per cent enzyme concentration in 4 hours scouring time and a pH 5.0.

Nowadays, bleaching of textile materials was also done by using enzymes such as laccase, glucose oxidase, proteases etc. Bio bleaching is frequently used on denim fabrics to bleach indigo colour and give denim a “wash down effect”. Enzymes frequently used for bio bleaching of denims are lipase, lactase. Cellulase enzyme was also used to get “salt and pepper effect” in denim fabrics.

According to Mazumder 2010 [7], sand blasting is one of the finishes done on denim fabric in which sand is sprayed at high pressure over the selected portion of the denim fabric. The sprayed sand removes colour from the specific portion of the fabric. Sand blasting makes the denim fabric stiffer, enzymatic washing of fabric is done by using 400 g of acidic enzyme i.e. cellulase at 50-55° C for 20 minutes to make fabric softer.

(Source:https://www.google.co.in/search?q=denim+washing+effects&source)

Fig 2: Wash Down Effect of Denim

Sreenath *et al*, 1996 [15] used cellulases, xylanase and pectinase enzymes for biopolishing of cotton/jute blended fabric to improve its softness. This enzyme removes the protruding fibres from the surface of the fabric and the reducing sugar released by these enzymes makes fabric softer. Amanuel and Teferi, 2017 [1] utilizes aloe gel for desizing cotton fabric. Aloe vera is a medicinal plant containing enzymes like amylase, aliiase, catalase, lipase, cellulose, alkaline phosphatase and carboxypepetidase. Aloe vera also contains minerals like calcium, sodium, copper, magnesium, zinc, chromium, manganese and iron. Minerals like manganese are essential components of enzymes which help in activation of enzymes present in the gel of aloe vera. Enzymatic cotton desizing was done using 50-60 g/l aloe gel with 5 g/l sodium chlorite at 70-80° C for 60 minutes. When desizing processes using aloe gel is compared with synthetic enzyme desizing, there was high amount of weight loss in aloe gel desizing which proves that this process is more efficient than synthetic enzyme desizing. The antiseptic components like sulphates, anthriquinones, salicylic acid of aloe vera gel also provides antibacterial finish to the cotton fabric.

Latest Technologies in Chemical Processing of Synthetic Textile Material

Synthetic fibres are frequently used in everyday applications from bristles of toothbrush to the clothes, glasses and home furnishings. Synthetic fibres first introduced in late 1930s with the introduction of nylon by American Dupont company, and gain popularity in 1960s when polyester arrived in textile industries. The ease of maintenance, wide number of beneficial properties like high strength, durability and easy recycling of polyester has continuous advantage over natural fibres. Another class of fibres is semisynthetic regenerated fibres such as rayon, lyocell and modal which are chemically regenerated using natural raw materials such as cellulose, wood pulp, cotton linters etc.

Surface Modification using Enzymes

Synthetic fibres have wide number of advantages such as high strength, chemical resistance, non-shrinkage. But the hydrophobicity and highly crystalline structure causes discomfort to the human skin and also generate problems in other finishing treatment such as dyeing. To improve the hydrophillicity of synthetic materials enzymes were proven to be beneficial alternative for surface modification. Mostly, sodium hydroxide was used to improve the hydrophillicity and flexibility of the synthetic fibres but due to increased weight loss and yellowing of synthetic fibres makes the chemical process unacceptable.

According to Silva and Paulo, 2008 [14] cutinase enzyme has the ability to modify the surface of polyester by hydrolysis of ether bonds. But Araujo *et al*, 2008 [2] stated that by using mutagenesis recombinant cutinase were developed which shows high hydrolytic activity in case of polyester and polyamide fabrics. In case of polyacrylonitrile (PAN) fibres which are more sensitive to yellowing of fibres, nitrile hydralase and amidase were used to improve the hydrophillicity and dye absorption capacity of PAN fibres.

Ibrahim and Salam, 2012 [4] studied the effect of enzymatic treatment on the digitally printed polyester fabric. The lipase enzyme used with 0.5 g/l concentration showed maximum colour strength (k/s value) and improvement in colour fastness properties of the polyester fabric. This is due to fact that lipase has increased the hydrophillicity of the polyester fabric which increased the absorption of printing paste inside the polyester fabric.

Use of Specialty Chemicals in Processing of Synthetic Fibres

Due to increasing awareness of green marketing among consumers, synthetic fibres production involves the use of specialty chemicals and ecofriendly agents in the processing.

Specialty chemicals are those which are used in relatively smaller amount and have high efficiency to enhance the chemical process. Mehra *et al*, 1996 [8] emphasized that the use of textile specialty chemicals will be the future demand in the textile industries. In the challenge of producing biodegradable products, textile industries are utilizing chemicals which are less harmful to the environment and replacing the old chemicals with those specialty chemicals having high efficiency in relatively low volumes.

Some of the examples of the specialty chemicals are formic acid, citric Ware substitutes of acetic and citric acid. Ginasol 6836 is a substitute of non-ionic detergents. The hydrocarbons used in the thickening agents of printing can be eliminated by using acrylic acid and divinyl benzene copolymers.

Surface modification using Laser treatment

The use of chemicals in textile processing is completely replaced by laser technologies. Laser induced processing of textiles provides advantages like ease of operation, reduced time, reduces labour cost and high efficiency. Laser technology is generally used for surface modification of synthetic fibres in order to improve its performance. Parvinzadeh, M. 2012 [11] stated that laser irradiation over polyester fibres have improved its wettability and air permeability. Yip *et al*, 2009 [19] used 193 nm argon fluoride excimer laser on nylon 6 fabrics and results showed the rippled like structure on the irradiated area because of breaking of long chain molecules.

Other Physical Treatments

Other physical treatments include vapour deposition method, sol gel technique, layer by layer deposition and corona discharge. According to Parvinzadeh, M. 2012 [11], these methods are used for surface modification of synthetic fibres such as PET (Polyethylene terephthalate), PAN (Poly acrylonitrile) and polyamide i.e. nylon. All these treatments help to improve the properties of synthetic textile materials such as dyeability, absorbency, softness, anti-static and anti-slipping. These treatments are advantageous in terms of economic as well as environmental perspective.

Conclusion

In the recent years various techniques of chemical processing have been evolved from breakthrough inventions. This sector of textile processing *viz.* chemical processing, utilizes huge amount of water and chemicals which leads to wastage of water and increased pollution load. The main findings of this review paper are how to reduce the effect of chemicals using sustainable techniques that not only save the environment but also helps in reducing the pollution load. Some recent inventions like specialty chemicals, laser technologies have proved them a boon for reducing the pollution from the environment in a very sustainable and eco-friendly manner. These recent technologies have not only contributed towards pollution control but also enhance the performance of natural and synthetic fibres by improving their physical and chemical properties. Previously, it was believed that the main aim of chemical processing in textile industries is to remove the dirt and dust particles from textile materials but with the advancement in this sector leads to enrichment of usefulness of textile materials. The future perspective of textile processing sector is to integrate the processing steps with utilization of highly advanced value added techniques for textile processing in order to meet the growing market demands. Therefore, it can be concluded that with the use of advanced technologies in an efficient manner creates a good scope for this sector and makes textile processing very easy with higher efficiency.

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