Eco-Friendly Textile Chemical Processing Methods

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ABSTRACT

This research focuses on the hazardous chemicals and auxiliaries used in the traditional textile wet processing including pretreatment, dyeing, printing and finishing processes. Such processes results in the contamination of soil, air, water and also affects all species in the eco-system. The harmful chemicals also have a serious impact on health of workers leading to diseases such as cancer, skin and respiratory related issues. Subsequently, in garments manufactured using the finishes fabrics treated with specific conventional wet processes causes adverse effects on the overall health of the consumers in multiple ways. Therefore, it is crucial to replace the conventional textile processing with sustainable alternatives, though these processes demand more investment and are costlier. The use of ecological, sustainable and biodegradable natural raw materials has increased as compared to synthetic raw materials in textile industry. Various eco-friendly processes such as enzymatic treatments, application of plasma technology for natural and synthetic fibers, application of ozone gas in textile wet processes and membrane filtration technology and facilitate to reduce the hazardous effects of conventional processing methods. This study focuses on recent developments in some environment friendly production methods in textile wet processing industry.

Keywords: Textile wet processing, ozone gas, membrane filtration technology, plasma technology, enzymatic treatment

INTRODUCTION

The current issues of pollution in chemical processing of textiles will be resolved to a major extent by applying clean production methods in future. This will also facilitate in saving resources like energy and water in the following four approaches:

1. Emphasis on latest technology of dyeing in environment having carbon dioxide, plasma, ozone technology, Transfer printing and enzymatic processes.

2. Use of chemicals which are eco-friendly

3. Purification process to re-use the water

4. Optimization of Process by ensuring lower quantity of consumption of water and chemicals alongwith lower temperature required for process to be carried out in a short time

The textile waste water is purified by numerous traditional methods like chemical coagulation (using ferrous and polyelectrolytes), biological treatment followed by activated carbon adsorption. However, large amount of sludge is being created by these processes. Subsequently, latest methods have been developed for full disposal of textile waste water (Aouni, A., et al., 2012).

Starch derivatives such as polyarcilate, polyvinylalcohol, carboxymethyl cellulose and heteropolysaccharides can be used instead of starch in pretreatment process of desizing. Other chemicals used for desizing have higher

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COD as compared to COD in starch. However, a major quantity of waste water is generated due to use of large amount of starch during desizing process. Environment pollution has now become a global concern as a result of higher industrialization. Approximately, more than 7,00,000 tons of dyes are manufactured as per the records. But, due to hazardous environment impacts, 2,80,000 tons of dyes are wasted and are not available for use. The toxic wastewater ultimately causes a lot of harm to the environment (Jegatheesan, V. et al.,2016, Ali, H, 2010 and Kant, R, 2012).

This review article focuses on environment friendly production methods applicable in textile industry such as enzymatic treatments, ozonation and plasma application and also membrane filtration for cleaning textile waste water.

RESEARCH METHODOLOGY

This research paper follows a research technique based on secondary research methods (Ref to Figure-1). Data has been collected from books, review papers, articles, academic papers, etc.

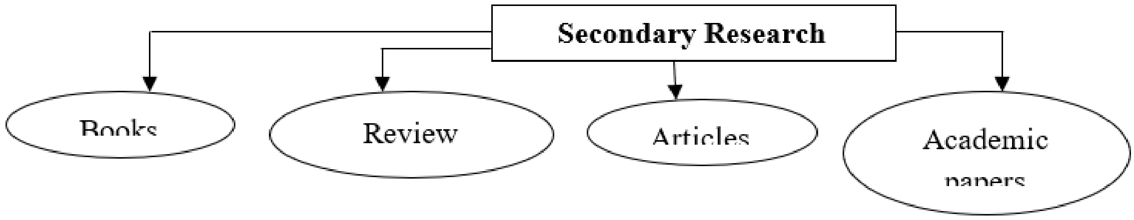

Figure-1 Details of the research methodology followed for this study

RESULTS AND DISCUSSION

Few eco-friendly production methods applicable in textile industry are summarized below:

Eco-Friendly Textile Wet Processing

The various stages in the textile chemical processing are shown in Figure 2

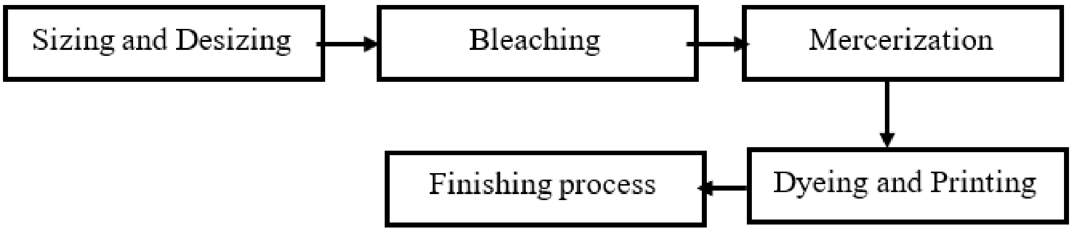

Figure 2: Textile chemical processing stages

Sizing and Desizing: The most widely used sizing agents in the preparatory process of weaving are carboxymethylcellulose (CMC), PVA and starch. Subsequent to the weaving process, these agents are removed from the fabric by the desizing process. Starch is converted to simple water soluble products by oxidation or enzymatic process. Desizing waste in the range of 300-450 ppm and pH 4-5 has more biological oxygen demand. Hydrogen peroxide can be utilized to convert starch into carbon dioxide and water, thus enabling the degradation of starch (Holkar C.R. et al., 2016).

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Bleaching: In this process, white fabric is attained by elimination of the natural coloring matter from the fabric. Hydrogen peroxide has replaced Sodium Hypochlorite which was used conventionally as a bleaching agent (Holkar C.R. et al., 2016).

Mercerization: This process improves tensile strength, dye uptake and lustre in cotton fabric. Sodium hydroxide of high concentration (18-24% by weight) is used for the treatment for approximately less than 4 minutes. Subsequently, the cotton fabric is treated with acid or water for 1-3 minutes under stress to neutralize Sodium hydroxide. For recycling Sodium hydroxide in the wash water, multiple effect evaporators or membrane techniques can be utilized (Holkar C.R. et al., 2016).

Dyeing and Printing: The dye is applied in the aqueous medium in dyeing process whereas in printing, a thick paste form of dye is used for application. The groups involved in dyeing of textiles for color uptake include carbonyl (-C=O), azo (-N=N-), nitro (-N=O), quinoid groups and auxochrome groups like carboxyl, sulphonate, amine and hydroxyl. The two major groups which causes textile waste water and contamination due to textile coloration are anthraquinone and azo groups. Both printing and dyeing processes have similar compounds in the waste generated (Holkar C.R. et al., 2016).

Finishing process: The objective of chemical and mechanical finishing processes is to modify the appearance, handle and performance properties of fabrics.

Each stage of the textile wet processing leads to generation of hazardous chemicals in the textile waste water as per the following details:

1. Sizes, starch, enzymes and waxes after completion of desizing process

2. Sodium hydroxide, surfactants, soaps, pectin, oils, fats, waxes and sizes after completion of scouring process

3. Hydrogen peroxide, sodium silicate, organic stabilizer and alkalies after completion of bleaching process

4. Dyes, color pigments, surfactants, alkalies, acids, metals, salts, formaldehyde, urea and solvents after completion of Dyeing and Printing process

5. Softeners, waxes, resins and solvents after completion of finishing process (Holkar C.R. et al., 2016).

Treatment Using Enzymes

Enzymes are biocatalysts which are made of metabolic products of live organisms acquired from bacterial derivatives. Biochemical or Chemical reaction involve catalysts and these stay the same even when the reaction is complete. Since 1910s, Amylases have been used to break down starch in textiles. In case of finishing of wool fabric, the enzymes are used to remove the flake layer on the surface and also to change the surface of fabric. The fabric is also imparted property of anti-felting and lustre (Paulo, A.C., et al., 2003).

Purpose of Bio-process for textile finishing

Cellulase enzyme is used for modifying properties of cellulosic fabrics. New type of enzymes have been developed for finishing processes of ramie, linen, cotton and blends with synthetic fibers. Bio-finishing processes for cellulosic fibers are widely used in textile finishing nowadays. Its objectives are to reduce nep, fiber fuzziness, fibrillation and bead formation and enable cleaning of fabric surfaces. The process increase flexibility, softness, fabric flow, hydrophilic character, smoothness, colorant attraction, color efficiency, lustre and water absorption in towels and batch textiles. It also imparts comfortable wearing characteristics. It is widely used for fabrics like cotton, linen and viscose with low basis weight without conformity in their elastic and resistance features. It helps to attain faded look and stone washing. Enzymes give softness when used together with softeners. The fabrics given bio-finishing treatment retain the finish even after multiple washing steps. Bio-finishing process has replaced numerous textile chemicals and it is environmentally friendly and does not lead to pollution. There is less quantity of waste generated and savings in energy and water consumption with the use of enzymes. (Galante, Y.M., et al., 2003 and Stohr, R., 1995).

Plasma Technology

Plasma technology finds application in textile industry due to its enormous advantages. Plasma is the fourth state of material which has the maximum energy. When energy is provided to a solid material, there is a rise in the distance between atoms, which results in higher vibrations. In such scenario, liquid form is generated on melting of the solid material. The atomic mobility rises during the process of imparting energy to this material. When sufficient energy is acquired by the material for evaporation, there is a free movement of atoms in random directions, during transition from the solid phase to the gaseous state. When energy is provided, molecules and atoms start decomposing into charged particles (electrons and ions), with the material transition to the plasma phase. The emergence of reactive particles in plasma applications causes material surface modifications. Cross-linking, grafting, surface activations, corrosion and cleaning are a part of these modifications. There are two categories of plasma treatment – hot plasma and cold plasma. Cold plasmas can be used in textile processing as it does not cause harm to fabric. Carbonization of textiles is attributed to Hot plasma applications. Non-thermal plasma treatment finds wide application in the Pre-treatment and Finishing processes of textiles. Plasma surface modification does not require chemicals and water in the process. As a result, plasma treatment is environment friendly and cost-effective process due to decrease of contaminations. Non-thermal plasma are quite appropriate, since most of fibers are sensitive to heat. By utilizing this technique, active functional groups are also generated on fabric surfaces. Other benefits of non-thermal plasma treatment are printability, created oleophobic properties, modified electrical or physical properties, increased wettability, adhesion of coatings and disinfection or cleaning of fiber surface (Morent, R., et al., 2008).

Plasma treatment to cotton

Plasma treatment can be used to alter various types of textiles. In case of cotton fibers, the application of plasma treatment has several advantages such as elimination of PVA based sizing (Cai, Z., et al., 2003), improvement in hydrophobic properties (Li, S., et al., 2007), development of adhesion properties (Gorjanc, M., et al., 2010), increase in wickability and hydrophilicity (Karahan, H.A., et al.,2008) and higher dyeability (Temmerman, E., et al., 2005). Cai et.al. used air/oxygen/Helium and air/Helium plasma treatment for desizing of PVA on cotton fabric. After the plasma treatment, tensile strength and % desizing ratio were evaluated. It was found that certain PVA sizing was eliminated due to plasma treatment and also there was tremendous enhancement in % desizing ratio by washing. There was similarity in tensile strength of cotton fabric treated with atmospheric plasma and unsized fabrics. PVA sizing is effectively eliminated with air/oxygen/Helium plasma (Cai, Z., et al., 2003). Argon atmospheric plasma and Air plasma were used for treatment on raw cotton fabric samples as per another research. It was observed that the wickability of samples and hydrophilicity improved and the contact angles got significantly reduced after the plasma treatment. Also, scanning electron microscope was used for noting the morphological modifications (Karahan, H.A., et al., 2008).

Plasma treatment to wool

Plasma treatment is applicable in case of wool fiber and has become popular. Ammonia low temperature plasma, carbon tetrafluoride and oxygen were used for treatment on wool fabrics. The samples were dyed with natural dyes extracted from gromwell, madder, cochineal and Chinese cork tree after the Plasma treatment. It was found that the wool fabrics treated with plasma showed higher rate of dyeing. Also, brightness of plasma treated wool fabrics dyed with Chinese cork tree and cochineal was more as compared with untreated wool (Wakida, T., et al., 1998).

The impact of Plasma treatment on the natural dyeing properties of wool fabrics was researched by Ghoranneviss et.al. Argon plasma was used for treatment of Wool fabric before undertaking the dyeing process. Natural dyes such as Weld and Madder were used alongwith Copper sulphate as a metal mordant. In a DC magnetron plasma sputtering device, copper was used as the electrode material.

The anti-bacterial properties, color fastness and color strength of samples were analysed after these processes. It was found that all the three parametres showed improvement after the plasma treatment of samples (Ghoranneviss, M., et al., 2011).

In another research, wool/cashmere and pure cashmere textiles were treated with atmospheric pressure plasma with a dielectric barrier discharge in humid air (air/water vapor mixture). The wettability of fabrics was attained by modifying the parameters of treatment. In order to evaluate the parameters such as surface morphologies, wettability, mechanical properties and chemical composition of the plasma treated samples, characterization analysis was conducted. It was found that the wettability of surface had increased due to a surface oxidation of the treated fabrics. Also, the fabric surface had a small etching effect as proved by SEM analysis (Zanini, S., et al., 2015).

In other study, the oleo and hydro-repellent modifications of wool/nylon and pure cashmere textiles were researched by treatment with atmospheric pressure plasma after impregnation with fluorocarbon resin. Dielectric barrier discharge in humid air (air-water vapour mixture) was used to apply the plasma treatment. A foulard system with an aqueous dispersion of a commercial fluorocarbon resin was used for performing the finishing process. Various parameters such as chemical composition, surface morphologies and wettability of the altered textiles were evaluated after the plasma treatment. It was found that the oleo and hydro-repellent properties of the altered fabrics improved due to the plasma treatment (Zanini, S., et al., 2016).

Plasma treatment to synthetic fibers

Atmospheric Plasma treatment can be used to change the surface of polyester even though it is chemically inert to most coatings. The surface becomes filled with oxygen and wetting increases after the Plasma treatment. It was also found that the adhesion increased after the Plasma treatment as evaluated by adhesion test (Rezaei, F., et al., 2017). The effects of air Plasma treatment on starch altered polyester and polyester were researched in another study. To develop the interfacial adhesion of starch to polyester, air plasma treatment was used on fabric. Parameters such as mechanical and thermal properties, wettability of samples were evaluated after the Plasma treatment. It was found that the contact angle of samples reduced instantly after giving Plasma treatment for a less time duration. Also, variation of thermal stability, elongation and flexural properties of polyester were observed as a result of Plasma treatment (Wiacek, A.E., et al., 2017).

Low pressure oxygen and argon plasma to modified fabrics and nylon was applied by Zhang et.al. Single-walled carbon nanotubes were coated on fabric samples by a dip-drying process after the alteration caused by plasma. Fiber surface roughness, sheet resistance and the attachment of Single-walled carbon nanotubes onto nylon fabrics were researched after the coating process got completed. All the three parametres showed improvement subsequent to the process of coating (Zhang, W., et al., 2012).

In another research, nylon 66 and Polypropylene fabrics were treated with atmospheric pressure Helium-oxygen and Helium plasma for certain time intervals of exposure by McCord et.al. No modifications in the samples were observed in scanning electron microscope. Oxygen and Carbon contents of nylon 66 got modified after the Plasma treatment. There was a notable improvement in the nitrogen and oxygen contents in samples of Polypropylene fabric. There was reduction in tensile strength of Nylon 66 fabric samples due to Plasma treatment (McCord, M.G., et al., 2002).

In another research, RF atmospheric pressure plasma was applied on acrylic fabric. Subsequently, samples were treated with fluorocarbon finish. Helium/oxygen and Helium gas were used for varying time periods in the application of plasma. Taking into consideration the type of gas and time required for processing, the water and oil repellency of samples were evaluated. It was found that the repellency properties of samples increased after the Plasma treatment. The morphology of samples also got modified after the Plasma treatment (Ceria, A., et al., 2010).

Applications of Ozone Gas in Textile Industry

Application of ozone gas in pre-treatment of fabric

Ozone gas is utilized in various sections of textile industry due to its numerous benefits. It is used as a substitute to Hypochlorite and Hydrogen peroxide in bleaching process as it is an oxidative material. As a bleaching agent, its benefits include less harm to fabrics, no waste generation and being harmless to human health and environment. Ozone gas also liberates energy and leads to lesser use of chemicals required for washing, saves water and also reduces the time required for process.

Surface modification of textile fibers utilizes Ozone gas alongwith Ultraviolet radiation. This is a dry and eco-friendly surface treatment used for solid surfaces and is cost-effective. Other advantages include improved surface adhesion which leads to superior quality products. Another feature of ozone and ultraviolet radiation which affects the surface wetting properties is Etching effect (Rahmatinejad, J. et al.,2016).

As it has more oxidative capacity and opportunities, researchers have studied the application of ozone in bleaching process of textiles. Ozonation treatment can result in bleaching of cotton fabric in a short period of time as compared to conventional bleaching process (Perincek, S.D. et al., 2007).

The impact of plasma-induced ozone treatment on the fading of colour in case of cotton fabric dyed with Reactive dyes was investigated. The steps include dyeing of cotton fabric with yellow Reactive dye and subsequently treatment of coloured fabric with plasma-induced ozone under varying conditions. Spectrophotometer was used to test the nature of fading of fabric. It was found that cost and stages required for processing were lowered as a result of plasma-induced ozone treatment (Kan, C.W. et al., 2016).

In other study, ozone injected water alongwith ultrasound and hydrogen peroxide was used for treatment on jean fabric. Electron paramagnetic resonance spectroscopy was used for studying effect on degradation of dye. It was concluded that effectiveness of ozone was more prominent for bleaching of jean samples than the hydroxyl radicals when added with ultrasonic energy. The diffusion of ozone through the fabric was improved due to ultrasonic cavitation which lead to indigo dye degradation. There was no harm caused to cotton fibers as a result of application of ozone in moderate concentration (Hamida, S.B. et al., 2017).

The effects of ozonation on bleaching and dyeing properties of Angora rabbit fibers was researched. It was observed that the dyeability and degree of whiteness of Angora rabbit fibers increased due to ozonation (Perincek, S., et al., 2008). Ozone alongwith ultrasound were applied on cotton fabric in another research. Various plant based natural dyes were used for dyeing the samples after completion of Pretreatment process. This mixture of ozone and ultrasound did not require any mordanting agents to be applied prior to the dyeing process. The dyed samples obtained have overall good colorfastness properties (Benli, H. et al., 2015). In a research conducted by Prabaharanet.al., ozone / oxygen gas mixture was used for bleaching of greige cotton fabric and the properties of bleached fabric due to effect of ozone concentration and time of treatment were analysed. Various parameters like extent of removal of impurities, elongation, Whiteness Index, strength, degree of chemical modification and uptake of Reactive dyes were studied after the bleaching process. As per the results, an acceptable value and result was found in a very short duration for Whiteness Index as compared to Ozonation.

The advantages of ozone bleaching are lesser consumption of water, low time consumption and environment friendly process (Prabaharan, M et al., 2000).

Application of ozone in sizing

In case of natural fibers, before the commencement of weaving, sizing agents are applied on the warp yarns to impart them the strength required to withstand the stresses imposed during weaving process. Poly-vinyl alcohol (PVA) has been a known sizing agent in textile industry due to its several advantages. However, there is a high level of chemical oxygen demand (COD) being generated due to trouble in decomposition of PVA waste water. To overcome these drawbacks, a few eco-friendly production methods are applied. Glycerol and Phosphate

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modified starch (PM-starch) were used by Sun et al. for cotton yarns sizing. It was found that breaking elongation, yarn breaking strength and sizing pick-up were reduced due to the usage of glycerol (Sun, S. et al.,2013)

Membrane Filtration Technology

One of the cost effective and efficient methods used for segregating components mixed in liquid is Membrane Filtration Technology. Membrane is a material obstruction comprising of a permeable film which facilitates the transfer of compounds to their chemical and physical behaviours (Munir, A, 2006).

Types of Membrane process

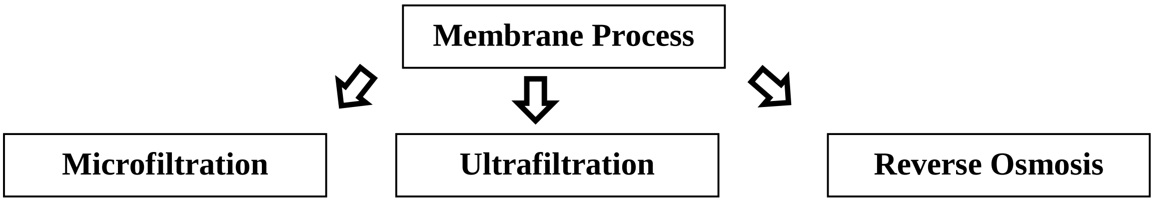

Figure 3: The three stages of Chemical processing in Textiles

There are three types of membrane processes as seen in Figure-3

Microfiltration: This process transfers particles with size 0.025 – 10 µm from liquids using a permeable film. Microfilteration process facilitates filtration of all bacteria at various stages. Since, the size of the viruses are smaller in comparison to the pores present in the Microfiltration membrane, they cannot be eliminated (Munir, A, 2006).

Ultrafiltration: It is a filtration technique which segregates micro particles and molecules which are mixed with fluids. The size of the molecule along with the physical and chemical attributes of the sample is the determining factor for effective filtration. Segregation of comparable sized molecules cannot be achieved through this process. However, this method is successful in segregating salt molecules and materials having 1-1000 K molecular weights (Munir, A, 2006).

Reverse osmosis: In this process segregation of membranes with smallest size of pores in the range of 0.0001 to 0.01 µm can be achieved. This segregation can take place without the use of any water. High Osmotic pressure is the key feature of reverse osmosis, which is more than Microfiltration. Salts and smaller molecules from solutions can be filtered at high pressure using membranes through reverse osmosis (Munir, A, 2006).

CONCLUSION

The recent developments related to environment friendly production methods used in textile wet processing sector are immensely beneficial to achieve sustainable processing of textiles. The ozone gas is used in various segments of textile wet processing including sizing and pre-treatment processes due to its numerous advantages. Membrane filtration technology which includes Ultrafiltration, Microfiltration and Reverse Osmosis processes is effectively used for cleaning of textile waste water. Plasma technology used for different fibers such as cotton, wool and synthetic fibers is another eco-friendly technology as an alternative to conventional textile chemical processes. Bio-finishing treatments with cellulase enzymes is another environment friendly process as it leads to less amount of waste generation.

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