A REVIEW OF TEXTILE PROCESSING AND IMPORTANCE OF MEMBRANE SEPARATION PROCESSES OR NANOFILTRATION OF DYE EFFLUENTS IN TEXTILE INDUSTRIES

Sukanchan Palit

Consultant, 43, Judges Bagan, Post
Office-Haridevpur, Kolkata-700082, India
Email: sukanchan68@gmail.com, sukanchan07@yahoo.com

ABSTRACT

Nanofiltration is an emerging and innovative area of environmental engineering science. This review discusses methods of treating effluents in textile industry. Several countries, like India has imposed strict and stringent ecological and environmental standards. So the need of environmental engineering practice. With more stringent standards in future, it is essential for control measures in textile industries. Industrial textile processing involves pretreatment, dyeing, printing and finishing operations. These production processes not only consumes large amounts of water but also produce substantial wastes. This manuscript combines a general overview of waste production from textile processes ,the work done in the area of nanofiltration of dyes and a broad idea of the vast and versatile area of nanofiltration.

I. INTRODUCTION

The textile dyeing industry consumes large quantities of water and produces large volumes of wastewater from different steps in the dyeing and finishing process. Wastewater from printing and dyeing units is often rich in colour, containing residues of reactive dyes and chemicals and requires proper treatment before being released to the environment. The toxic effects of dyestuffs and other organic compounds, as well as acidic and alkaline contaminants, from industrial establishments on the general public are widely accepted. Increasing public concern about environmental issues has led to closure of several small-scale industries.

Interest in ecologically friendly, wet-processing textile techniques has increased in recent years because of increased awareness of environmental issues throughout the world. Consumers in developing countries are demanding biodegradable and ecologically friendly textiles. Cotton provides an ecological friendly textile. Unfortunately dyes are unfavourable from ecological point of view because the effluents generated are heavily coloured, contain high concentration of salts and exhibit high biological oxygen demand/chemical oxygen demand values. In dyeing textiles, ecological standards are strictly applied throughout the processing from raw material selection to final product. This has become more critical since the German environmental standards are applied. The main challenge for the textile industry is to modify production methods and impose strict environmental standards in the production – shop floor.

II. VISION OF THIS REVIEW

The main challenge for the textile industry today is to modify production methods, so that they are more ecologically or environmental friendly at a reasonable and competitive price by using safer dyes and chemicals and by reducing cost of effluent treatment/disposal. Recycling is an alternative but pollution control methods are needed. There are three methods to reduce the pollution: 1. use of less polluting technologies 2. effective treatment of effluent so that it conforms to stringent standards 3. recycling waste.

The aim and objective of the review is to discuss various processing stages of the textile industry and the methodologies to treat textile effluent. A variety of water treatment and waste treatment are discussed in details from nanofiltration point of view. General and conventional treatment techniques are discussed with the vision of nanofiltration.

III. EFFICACY OF TEXTILE OPERATIONS-ITS VIEWPOINT

The textile industry comprises a diverse group of operations that process textile related products(fibre, yarn and fabric) for further processing into apparel, home furnishings and industrial goods. Textile establishments receive and prepare fibres, transform fibres into yarn and thread, and dye and finish these materials into useful end products.

The process of converting fibres into finished apparel is done by textile industries. There is little difference between knitting and weaving in the production of man made cotton and other fabrics. Textiles generally go through three or four stages of production that may go through several processes that may include yarn formation, fabric formation, wet processing and textile production.

3.1 Desizing component in textile processing and the importance of nanofiltration

The presence of sizing ingredients in fabric hinders and objects to processes such as dyeing, printing and finishing. For example, the presence of starch can hinder the penetration of dye in the fibre, which necessitates removal of starch prior to dyeing or printing. Starch is removed or converted into water-soluble products either by hydrolysis or oxidation.

In general about 50% of water pollution is due to waste water in desizing that has a high BOD that renders it unusable. The problem can be mitigated by using enzymes that degrade starch into ethanol.

The ethanol can be recovered by distillation for use as a solvent or fuel there by reducing the BOD load.

Alternatively an oxidative system like H_2O_2 can be used to fully degrade starch to CO_2 and H_2O_2. Electro-oxidation of RuO_2/Ti or PbO_2 or PbO_2/Ti electrodes is an effective method for treating starch effluent. Considering the cost of effluent treatment, the cost of synthesizing sizing formulations is negligible. Today advances in nanofiltration and ultrafiltration techniques allow recovery and reuse of polyvinyl acrylic (PVA).

Compared with reverse osmosis, nanofiltration is less expensive and can be used from treatment of industrial effluents. Moreover, a higher retention of dyes and other low molecular weight compounds(Mol Weight-200-1000) is achievable by nanofiltration. The salt rich permeate can be reused in the preparation of dye baths which minimizes the amount of waste nanofiltration. The basic problems involved in any membrane separation process are a drop in flux and membrane fouling. To overcome these processes, combinations of various separation methods are employed.

3.2 Mercerization of textile fibres

In order to improve luster, increase strength and improve dye intake, cotton fibre and fibre and fabric are mercerized in the gray state after bleaching. Essentially, mercerization is carried out by treating cotton fibres with a strong solution of sodium hydroxide and washing off the caustic after 1 to 3 minutes while holding the material under tension. Cotton is known to undergo a longitudinal shrinkage upon impregnation with solution. This can be prevented by stretching it or holding under tension. The material acquires the desired properties of luster, increased strength, dye intake and increased absorbancy.

The large concentrations of NaOH can be removed by membrane separation processes. The process is absolutely eco-friendly.

3.3 Bleaching

Natural colour matter in the yarn imparts a creamy appearance to the fabric. In order to obtain white yarn that facilitates producing pale and bright shades, it is necessary to decolorize the yarn by bleaching. Hypochlorite is one of the oldest industrial bleaching agents. The formation of highly toxic chlorinated by-products during the bleaching process is reduced by adsorbable organically bound halogen (AOX).

Over the last few years, hypochlorite is replaced by other bleaching agents. It decomposes to oxygen and acetic acid which is completely biodegradable.

3.4 Neutralization

Replacement of acetic acid by formic acid for neutralization of fabric after scouring, mercerization, bleaching and reduction process is effective, economic and environment friendly.

3.5 Dyeing- the most important stage with regards to pollution

Treatment of fibres or fabrics with chemical pigments to impart colour is called dyeing. The colour arises from chromophore and auxochrome groups in the dyes which also cause pollution. In the dyeing process, water is used to transfer dyes and in the form of steam to heat the treatment baths. Cotton which is world's most widely used fibre is a substrate that requires a large amount of water for processing. For example,to dye 1 kg of cotton with reactive dyes, 0.6-0.8 kg of NaCl, 30-60 g of dyestuff and 70-150 L of water are required. .More than 80000 tons of reactive dyes are produced and consumed each year. Once the dyeing operation is over, the various treatment baths are drained, including the highly coloured dye bath which has high concentration of salts and organic substances. The wastewater must be treated before use. Coagulation and membrane separation processes(nanofiltration and reverse osmosis) are the processes suggested for treatment of this water, however,these treatments are only effective with very dilute dye baths. Dye baths are generally heavily polluted. For example, wastewater produced by reactive dyeing contains hydrolyzed reactive dyes not fixed on the substrate(representing 20 to 30%of the reactive dyes applied on an average of 2 g/l). The residual amount is responsible for the colouration of the effluents and cannot be recycled. Dyeing auxillaries or organic substances are non-recyclable and contribute to the high BOD/COD of the effluents.

Membrane technologies are increasingly being used in the treatment of wastewater for the recovery of valuable components from the waste stream, as well as for reusing the aqueous stream. A number of studies deal with application of various pressure driven membrane separation processes in the treatment of wastewater from dyeing and finishing process.

Measures adopted for the abatement of pollution of different dyes are 1. use of low material-to-liquor ratios 2. use of trisodium citrate 3. replacement of reducing agent(sodium hydrosulphite) with a reducing sugar or electrochemical reduction 4. use of suitable dye-fixing agents to reduce water pollution loads.

One researcher first reported the concept of totally ecologically friendly mordents or natural mordents during dyeing with natural dyes. Some other researchers were the first to point out that natural dye shades could be built-up by a multiple dip method that renders natural dyeing more economical. Dyeing of natural and synthetic fibres with natural dyes has been the subject of several studies. Development of ecologically friendly non-formaldehyde dye fixative agents for reactive dyes was recently reported.

3.6 Printing

Printing is a branch of dyeing. It is generally defined as localized dyeing. i.e. dyeing that is confirmed to a certain portion of the fabric that constitutes the design. It is really a form of dyeing in which the essential reactions involved are the same as those of dyeing. In dyeing, colour is applied in the form of a solution, whereas in printing colour is applied in the form of a thick paste of the dye. The fixation of the colour in printing is brought about by a suitable after-treatment of the printed material.

Textile fabric printing produces hydrocarbon effluents that must be removed before they reach the atmosphere. Limits on emissions will become more restrictive in future, which makes cleaning an environmental priority. In India, a majority of textile printing units prefer to use kerosene in printing because of the brilliant prints and ease of application. In India alone, about 122 million litres of kerosene is released into the atmosphere annually during printing, drying and curing. The resulting pollution of the atmosphere and the wastage of hydrocarbon products is colossal. Air-laden kerosene is harmful to human beings as well as to flora and fauna in the neighbourhood. Therefore it is imperative that as much as kerosene as possible is recovered from the exhaust pipes of the printing industry.

The most common chemical in reactive dye printing is urea, which leads to high pollution load. A number of attempts have been made to limit or eliminate the use of urea in the print paste to reduce the effluent load.

Printing is mainly done by a flat or rotary screen, and after every lot of printing some residual paste is left in the wastewater. This can be used for printing of similar shades by adding new stock. Recently, screen free printing methods such as ink-jet printing and electrostatic printing have been developed that make use of an electronic control of colour distribution on fabric. Screen-free printing methods are attractive for pollution mitigation.

3.7 Finishing

Both natural and synthetic textiles are subjected to a variety of finishing processes. This is done to improve specific properties in the finished fabric and involves the use of large number of finishing agents for softening, cross-linking and water proofing. All of the finishing processes contribute to water pollution.

Among the products that are used in textile finishing, the most ecologically friendly ones are formaldehyde – based cross-linking agents that bestow desired properties, such as softness and stiffness that impart bulk and drape properties, smoothness to cellulosic titles. It can also enhance dimensional stability.

IV. MEMBRANE PROCESSES

Increasing cost of water and its enormous consumption necessitate a treatment process that is integrated with in-plant water circuits rather than as subsequent treatment. From this point of view, membrane filtration offers a dynamic choice. Processes using membranes provide interesting possibilities for the separation of hydrolyzed dye stuffs and dyeing auxillaries that simultaneously reduce colouration and BOD/COD of the wastewater. The choice of the membrane process, whether it is reverse osmosis, nanofiltration, ultrafiltration or microfiltration must be guided by the quality of final product.

4.1 Reverse Osmosis

Reverse osmosis membranes have a retention rate of 90% or more for most types of ionic compounds and produce a high quality of permeate. Decouration and elimination of chemical auxillaries in dye house wastewater can be carried out in a single step by reverse osmosis. Reverse osmosis permits the removal of all mineral salts, hydrolysed reactive dyes and chemical auxillaries. It must be noted that the higher concentration of dissolved salt, the more important the osmotic pressure becomes,therefore the greater the energy required for the separation process.

4.2 Nanofiltration

Nanofiltration has been applied for the treatment of coloured effluents from the textile industry. A combination of adsorption and nanofiltration can be adopted for the treatment of textile dye effluents. The adsorption step precedes nanofiltration, because this sequence decreases concentration polarization during the filtration process which increases the process output. Nanofiltration membranes retain low molecular weight organic compounds, divalent ions, large monovalent ions, hydrolysed reactive dyes and dyeing auxillaries. Harmful effects of high concentrations of dyes and salts in dye effluents have frequently been reported. The treatment of dyeing wastewater by nanofiltration represents one of the rare applications possible for treatment of solutions with highly concentrated and complex solutions.

A major problem is the accumulation of dissolved solids, which makes discharging the treated effluents into water streams impossible. Various research groups have tried to develop ecomomically feasible technologies for effective treatment of dye effluents.

Nanofiltration treatment as an alternative has been found to be fairly satisfactory. The technique is also favourable in terms of environmental regulations.

4.3 Ultrafiltration

Ultrafiltration enables elimination of macromolecules and particles, but the elimination of macromolecules and particles, but the elimination of polluting substances, such as dyes, is never complete(it is only between 31% and 76%).Even in the best of cases, the quality of treated wastewater does not permit its reuse for sensitive processes, such as dyeing of textile. Ultrafiltration can only be used as a pretreatment for reverse osmosis or in combination with a biological reactor.

4.4 Microfiltration

Microfiltration is suitable for treating dye baths containing pigment dyes as well as for subsequent rinsing baths . The chemicals used in dye baths, which are not filtered by microfiltration will remain in the bath. Microfiltration can also be used as a pretreatment for nanofiltration or reverse osmosis.

V. SCIENTIFIC RESEARCH PURSUIT IN THE AREA OF NANOFILTRATION OF DYES

The textile industry uses enormous quantities of water which in many cases are disposed to the environment with inadequate treatment. The effluent contains high salts and organic concentration and they are therefore difficult to be treated. In this work the effluents from the cotton textile industry was treated by nano-filtration membrane in order to reduce the quantity of the disposed water and at the same time to reuse the treated water (Avlonitis, 2008).

An excellent performance for the TRISEP (4040-XN-TSF) nano-filtration membrane was found by these researchers. They reduced the total salt concentration by more than 70%.

Pazdizor(2009) integrated nano-filtration and biological processes for textile wastewater treatment. The implementation of the biological anaerobic – aerobic system in separated reactors to the nano-filtration concentrate treatment was presented. The concentrate was obtained during the nano-filtration of the textile wastewater containing azo-dye Reactive Red 120. The experiments were conducted on the wastewater concentrated from 2 to 10 times. The goal of this research work was to present the implementation of the anaerobic-aerobic system in the separated reactors (two sludge system). A review on textile technology in cotton textile processing and its waste generation and effluent treatment was done by (Babu, 2007). This review discusses cotton textile processing and methods of treating effluent in the textile industry. Industrial textile processing comprises pre-treatment, dyeing, printing and finishing operations. These production processes not only consume large amounts of energy and water, but they also produce substantial waste products.

VI. NANOFILTRATION AS OF VISIONARY IMPORTANCE

Nanofiltration is projected as of primary importance in textile industry. Wastewater treatment is a continuous and constant problem in textile industry. Dyes are recalcitrant to conventional treatments. So the research and thought of alternative processes such as membrane separation processes and advanced oxidation processes. Advanced oxidation processes mainly ozonation can create wonders for textile industry. Membrane separation processes or nanofiltration are pathbreaking and visionary processes which can create revolution and stir in the textile industry by its environmental and ecological concern. Treatment of textile effluent dyes can have a permanent solution with membrane separation processes or advanced oxidation process. Research in this area will open an area of innovation and scholarly brilliance for environmental engineering and environmental science.

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