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TEXTILE TECHNOLOGY COTTON TEXTILE PROCESSING: WASTE GENERATION AND TREATMENT

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ABSTRACT

This review discusses cotton textile processing and methods of treating effluent in the textile industry. Several countries, including India, have introduced strict ecological standards for textile industries. With more stringent controls expected in the future, it is essential that control measures be implemented to minimize effluent problems.

Introduction

The textile dyeing industry consumes large quantities of water and produces large volumes of wastewater from different steps in the dyeing and finishing processes. Wastewater from printing and dyeing units is often rich in color, containing residues of reactive dyes and chemicals, and requires proper treatment before being released into 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 developed countries are demanding biodegradable and ecologically friendly textiles (Chavan, 2001). Cotton provides an ecologically friendly textile, but more than 50% of its production volume is dyed with reactive dyes. Unfortunately, dyes are unfavorable from an ecological point of view, because the effluents generated are heavily colored, contain high concentrations of salts, and exhibit high biological oxygen demand/chemical oxygen demand (BOD/COD) values.

In dyeing textiles, ecological standards are strictly applied throughout processing from raw material selection to the final product. This has become more critical since the German environmental standards regarding dye effluents became effective (Robinson et al., 1997). The main challenge for the textile industry today is to modify production methods, so they are more ecologically friendly at a competitive price, by using safer dyes and chemicals and by reducing cost of effluent treatment/disposal. Recycling has become a necessary element, not because of the shortage of any item, but because of the need to control pollution. There are three ways to reduce pollution: (1) use of new, less polluting technologies; (2) effective treatment of effluent so that it conforms to specified discharge requirements; and (3) recycling waste several times over before discharge (Sule and Bardhan, 1999), which is considered the most practical solution.

The objective of this review is to discuss the various processing stages in the textile industry and the methodologies adopted for treating textile waste-water. A variety of water treatment techniques (Table 1) are discussed from an environmental point of

Industrial textile processing comprises pretreatment, dyeing, printing, and finishing operations. These production processes not only consume large amounts of energy and water, but they also produce substantial waste products. This manuscript combines a discussion of waste production from textile processes, such as desizing, mercerizing, bleaching, dyeing, finishing, and (. printing, with a discussion of advanced methods of effluent treatment, such as electro-oxidation, bio-treatment, photochemical, and membrane processes.

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view. Conventional and novel techniques discussed include electro-oxidation, biological treatment, photochemical processing, ion-exchange, and a variety of membrane .techniques.

TEXTILE OPERATIONS

The textile industry comprises a diverse and fragmented group of establishments that produce and/or process textile-related products (fiber, yarn, and fabric) for further processing into apparel, home furnishings, and industrial goods. Textile establishments receive and prepare fibers; transform fibers

The process of converting raw fibers into finished apparel and non-apparel textile products is complex, so most textile mills specialize. There is little difference between knitting and weaving in the production of man-made cotton and wool fabrics (Hashem et al., 2005). Textiles generally go through three or four stages of production that may include yarn formation, fabric formation, wet processing, and textile fabrication. Some of the steps in processing fibers into textile goods are shown in Figure 1. A list of some wastes that may be generated at each level of textile processing are provided in Table

Desizing. The presence of sizing ingredients \n the fabric hinders processes, such as dyeing, printing, and finishing. For example, the presence of starch can hinder the penetration of the dye into the fiber, which necessitates removal of starch prior to dyeing or printing. Starch is removed or converted into simple water-soluble products either by hydrolysis (by enzymatic preparations or dilute mineral acids) or by oxidation (by sodium bromide, sodium chlorite, etc.) (Batra, 1985).

In general, about 50% of the water pollution is due to waste water from desizing, which has a high BOD that renders it unusable. The problem can be mitigated by using enzymes that degrade starch into' ethanol rather to anhydro glucose. The ethanol can be recovered by distillation for use as a solvent or fuel, thereby reducing the BOD load. -

Cornstarch waste is easily degraded by treatment a mixed activated sludge **system. The** bio-kinetic coefficients were calculated from the two-level activated sludge operational processes using influent COD concentrations and four values of solid retention time. The results

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indicate that the effluent COD is related to the influent COD concentration. It is also proportional to the product of the influent COD and the specific growth rate. A multiple-substrate model was developed to predict the effluent COD under variable influent COD concentrations (Bortone et al_ 1995). There was no sludge-bulking problem apparently because of high dissolved oxygen (DO) concentrations, a buffered system, and a balanced C:N:P ratio; however, the critical DO concentration at which the sludge volume index began to rise increased as the food for microorganism (F/M) ratio increased. A cost analysis was provided for a hypothetical wastewater plant with a flow rate of 300m^3/ day (Vanndevivera and Bianchi, 1998). Synthetic sizing formulations based on poly vinyl acrylic (PVA) and acrylic resins, instead of starch, are expensive. Considering the cost of effluent treatment, the cost of synthetic sizing formulations is negligible. Today, advances in nano-filtration and ultra-filtration techniques allow recovery and reuse of PVA (Meier et al., 2002; Yuetal., 2001).

Compared with reverse osmosis, nanofiltra-tion is less energy intensive and can be used for the treatment of various industrial effluents (Meier et al., 2002). Moreover, a higher retention of dyes and other low molecular weight organic compounds (MW: 200-1000) is achievable by nanofiltration. The salt-rich permeate can be reused in the preparation of dye baths, which minimizes the amount of wastewater mat needs to be processed. The basic problems involved in any membrane-based process are a drop in flux ano[1] membrane fouling. To overcome mis problem and to achieve a high quality separation, combinations of various separation methods have been adopted in recent years (Pigmon et al., 2003; Abdessemed and Nezzal, 2002; Dhale et al., 2000; Xu et al., 1999).

Mercerization. In order to impart luster, increase strength, and improve dye uptake, cotton fiber and fabric are mercerized in the gray state after bleaching. Essentially, mercerization is carried out by treating cotton material with a strong solution of sodium hydroxide (about 18-24%) and washing-off the caustic after 1 to 3 min, while holding the material under tension. Cotton is known to undergo a longitudinal shrinkage upon impregnation with this solution. This can be prevented by stretching it or holding it under tension. The male-rial acquires the desired properties of luster, increased strength, dye uptake, and increased absorbency. The large concentrations ofNaOH in the wash water can be recovered by membrane techniques. Use of ZnCfe as an alternative method leads to an increase in the weight of fabric and in dye uptake, and allows easy recovery of NaOH. Moreover, the process is ecologically friendly and does not require neutralization by acetic or formic acid (Karim et al., 2006).

Bleaching. Natural color 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 organic by-products during the bleaching process is reduced by adsorbable organically bound halogen (AOX).

Over the last few years, hypochlorite is being replaced by other bleaching agents (Rott and Minke, 1999). An environmentally safe alternative to hypochlorite is peracetic acid. It decomposes to oxygen and acetic acid, which is completely biodegradable. One of the advantages of peracetic acid is higher brightness values with less fiber damage (Rott and Minke, 1999). Recently, a one-step preparatory process for desizing, scouring, and bleaching has helped to reduce the volume of water. The feasibility of a one-step process for desizing, scouring, bleaching, and mercerizing of cotton fabric followed by dyeing with direct dyes has been discussed by Slokar and Majcen (1997).

Cooper (1989) suggested an economical and pollution-free process for electrochemical rnercer-ization (scouring) and bleaching of textiles. The process does not require conventional caustic soda, *I* acids, and bleaching agents. The treatment is carried j out in a low-voltage electrochemical cell. The base required for mercerization (scouring) is produced in the cathode chamber, while an equivalent amount of acid is produced in the anode chamber, which is used for neutralizing the fabric. Gas diffusion electrodes simultaneously generate hydrogen peroxide for bleaching. With a bipolar stack of electrodes., diffusion electrodes can be used as anode or cathode or both. The process does not produce hydrogen bubbles at the cathode, thereby avoiding hazards involving the gas (Lin and Peng, 1994),

An electrochemical treatment was developed for the treatment of cotton in aqueous solution containing sodium sulphate. In this technique, the current nanofiltration, because this sequence decreases concentration polarization during the filtration process, which increases the process output (Chakraborty et al., 2003). Nanofiltration membranes retain low-molecular weight organic compounds, divalent ions, large monovalent ions, hydrolyzed reactive dyes, and dyeing auxiliaries. Harmful effects of high concentrations of dye and salts in dye house effluents have frequently beetTfeported (Tang and Chen, 2002; Koyuncu, 2002; Bruggen et al., 2001; Jiraratananon et al., 2000; Xu et al., 1999; Erswell et al., 1988). In most published studies concerning dye house effluents, the concentration of mineral salts does not exceed 20 g/L, and the concentration of dyestuff does not exceed 1.5 g/L (Tang and Chen, 2002). Generally, the effluents are reconstituted with only one dye (Tang and Chen, 2002; Koyuncu, 2002; Akbari et al., 2002), and the volume studied is also low (Akbari et al., 2002). The treatment of dyeing wastewater by nanofiltration represents one of the rare applications possible for the treatment of solutions with highly concentrated and complex solutions (Rossignol et al., 2000; Freger et al., 2000; Knauf et al., 1998; Peuchot, 1997; Kelly and Kelly, 1995).

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 economically feasible technologies for effective treatment of dye effluents (Karim et al., 2006; Cairne et a!., 2004; Rott and Mike, 1999). Nanofiltration treatment as an alternative has been found to be fairly satisfactory. The technique is also favorable in terms of environmental regulation.

CONCLUSIONS

Waste minimization is of great importance in decreasing pollution load and production costs. This review has shown that various methods can be applied to treat cotton textile effluents and to minimize pollution load. Traditional technologies to treat textile wastewater include various combinations of biological, physical, and chemical methods, but these methods require high capital and operating costs. Technologies based on membrane systems are among the best alternative methods that can be adopted for large-scale ecologically friendly treatment processes. A combination methods involving adsorption followed by nanofiltration has also been advocated, although a major drawback in direct nanofiltration is a substantial reduction in pollutants, which causes permeation through flux.

It appears that an ideal treatment process for satisfactory recycling and reuse of textile effluent water should involve the following steps. Initially, refractory organic compounds and dyes may be electrochemically oxidized to biodegradable constituents before the wastewater is subjected to biological treatment under aerobic conditions. Color and odor removal may be accomplished by a second electro-oxidation process. Microbial life, if any, may be destroyed by a photochemical treatment. The treated water at this stage may be used for rinsing and washing purposes; however, an ion-exchange step may be introduced if the water is desired to be used for industrial processing.

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