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Decolourization of textile effluents

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ABSTRACT

Textile industry is one of the major industries in the world that provide employment with no required special skills and play a major role in the economy of many countries. The textile industry utilizes various chemicals and large amount of water during the production process. The water is mainly used for application of chemicals onto the fibres and rinsing of the final products. The waste water produced during this process contains large amount of dyes and chemicals containing trace metals such as Cr, As, Cu and Zn which are capable of harming the environment and human health. The textile waste water can cause haemorrhage, ulceration of skin, nausea, skin irritation and dermatitis. The chemicals present in the water block the sunlight and increase the biological oxygen demand thereby inhibiting photosynthesis and reoxygenation process. The environmental issues associated with residual colour in textile effluents have posed a major challenge to environmental scientists as well as the textile industries. The requirements to remove colour from textile effluent prior to discharge have been progressively restricted due to increased public complaints. Dyes are highly dispersible aesthetic pollutants and are difficult to treat, as most dyes are highly stable molecules made to resist degradation by light, chemical, biological and other treatment or exposure. There has been a lot of research going in the past few decades to develop efficient and cost effective technologies to remove colour from textile effluent. The present paper presents a significant review of the current literature available on various textile wastewater decolourization techniques being applied and researched to remove colour from textile wastewater.

Key Words : Biological oxygen demand, Chemical oxygen demand, Decolourization, Dyes, Textile effluent, Wastewater

INTRODUCTION

Textile industry is one of the leading contributors to many Asian economies including India, as it contributes nearly fourteen per cent of the total industrial production. It is also one of the biggest consumers of potable water as well as the chemical additives during various steps of textile processing (Verma *et. al*., 2012). Wet processing operations during textile chemical processing *i.e.* desizing, scouring, bleaching, dyeing, printing and finishing are the major causes of water pollution. Pollution is created by release of wastewater from residences,

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institutions, hospitals, commercial and industrial establishments. Toxic and hazardous pollutants are found in the industrial effluents; one particular class of synthetic chemicals which is of major concern is synthetic dyes and dye intermediates.

A major contribution to colour in textile waste water is usually the dyeing and washing operation. During dyeing, most of the dye is exhausted on the fibre, but the unfixed dye goes into wastewater causing deep colour (Joshi *et. al*., 2004). Wastewater released during dyeing and finishing process possess complex characteristics such as strong colour due to the presence of residual dyes, high pH, dispersants, leveling agents, acids, alkalies and large amount of suspended solids (SS). This increases the chemical and biochemical oxygen demand (COD and BOD), alters the pH and gives the water bodies (rivers) intense colourations (Agarry and Ajani, 2011). Presence of very high concentrations of these dyes can be highly visible and hence, the receiving water bodies not only become aesthetically unacceptable but also the discharge of these effluents can be carcinogenic, mutagenic and generally very harmful to the environment (Verma *et. al*., 2012).

Thus, these industries are facing problems in maintaining a profitable level of production while reducing the intake of fresh water. Another problem is the disposal of large volumes of effluents which abides by environmental standards (Muhammad *et. al*., 2008).

Environmental impact :

Coloured wastewater from textile industries is rated as the most polluted in almost all industrial sectors. Tremendous amount of dyes in textile sectors are continuously being exhausted in wastewater streams due to their poor adsorb ability to the fiber (Agarry and Ajani, 2011). Colour is defined as either true or apparent colour. True colour is the colour of water from which all turbidity has been removed. Apparent colour includes any colour that is due to suspended solids in the water sample. Colour and turbidity both cause an unaesthetic and real hazard to the environment. Table 1 and Fig. 1 present the permissible limit of effluent components in wastewater and percentage of wastewater discharge from various textile units.

The hazards caused by colour and solids in waste are dye toxicity and the ability of the colouring agents to interfere with the transmission of light through the water, thus hindering photosynthesis in aquatic plants. Heavy metals, typically copper and chromium are very hazardous to human and aquatic life at relatively low concentrations. Heavy metals are

Table 1 : Permissible limit of effluents in textile wastewater

Parameters	Permissible limit
pH	6.5 – 8.5
Biochemical Oxygen Demand (mg/L)	100 – 300
Chemical Oxygen Demand (mg/L)	150 – 250
Total Suspended Solids (mg/L)	100 – 600
Total Dissolved Solids (mg/L)	500 – 2000
Chloride (mg/L)	250 – 1000
Total Nitrogen (mg/L)	70 – 100

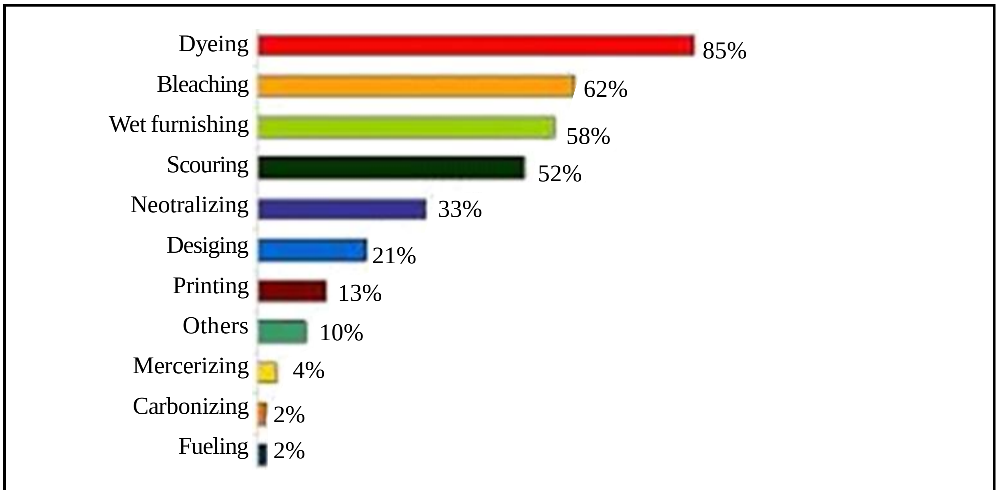

Fig. 1 : Percentage of wastewater discharge from various units of textile industry

introduced into the wastewater of textile manufacturing through the use of parameterized dyes and heavy metal after washes, which are used to increase the light fastness of the finished product. Total dissolved solids characterize the general purity of water and is often largely due to soluble ions such as sodium, chloride and sulphate. Obviously, high TDS is detrimental to fresh water aquatic life (Shanmugasundaram, 2007).

Need for textile effluent treatment :

The treatment of textile effluents is of interest due to their toxic and esthetical impacts on receiving waters. While much research has been performed to develop effective treatment technologies for wastewaters containing dyes, no single solution has been satisfactory for remediating the broad diversity of textile wastes. The nature of waste from the textile industry depends on the type of factory, the processes being operated and the fibres used. In general, however, textile wastewater is highly coloured. Around 10–15 per cent of all the dyes used in the industry are released into the environment during manufacture or usage.

Decolourization techniques :

There are several reported methods for the removal of pollutants from effluents. The technologies can be divided into four categories: physical, chemical, physico-chemical and biological. Because of the high cost and disposal problems, many of these conventional methods for treating dye wastewater have not been widely applied at large scale in the textile and paper industries. At present, there is no single process capable of adequate treatment, mainly due to the complex nature of the effluents. In practice, a combination of different processes is often used to achieve the desired water quality in the most economical way.

Physical treatment :

Physical methods of wastewater treatment accomplish removal of substances by use of naturally occurring forces, such as gravity, electrical attraction, and van der Waal forces, as well as by use of physical barriers. In general, the mechanisms involved in physical treatment do not result in changes in chemical structure of the target substances. Physical wastewater treatment includes adsorption, membrane filtration, and activated carbon.

Adsorption :

Adsorption is the phenomenon by which the molecules of a gas, vapour or liquid spontaneously concentrate at contacting surface without undergoing any reaction. It is an effective method for lowering the concentration of dissolved organics in an effluent. The use of any adsorbent, whether ion-exchanger, activated carbon or high surface area inorganic material for removing species from a liquid stream depends on the equilibrium between the adsorbed and the free species (Joshi *et al*., 2004).

Activated carbon :

Activated carbon has been used extensively for the treatment of different classes of dyes *i.e.*, acid, direct, basic, disperse, reactive, etc and is now the most widely used adsorbent for dyes. Disperse, vat dyes and pigments have low solubility in water that their rate of adsorption on carbon is prohibitively slow at room temperature. On the other hand, water soluble dyes such as acid, basic, direct, metallised mordant and reactive dyes are also not readily adsorbed on carbon. The main reason is the polar nature of these dyes v/s the non-polar nature of carbon. Therefore, activated carbon when used in combination with polymer flocculation, chemical coagulation or biodegradation, it becomes a very useful step for efficient dye removal. Factors such as choice of activated carbon, temperature, pH, contact time and dosage must be taken into consideration for optimum removal of dyes from wastewater.

Membrane filtration :

Membrane filtration technology is extensively applied in process industries to concentrate, purify and improve the final product. It can be sub divided into four categories *viz*., reverse osmosis, nano filtration, ultra filtration and micro filtration (Joshi *et. al*., 2004). Membrane filtration has some special features unrivalled by other methods like resistance to temperature, adverse chemical environment and microbial attack. The concentrated residue left after separation, poses disposal problems and high capital cost and possibility of clogging and membrane replacement are its disadvantages. This method is suitable for water recycling within a textile dye plant, if the effluent contains low concentrations of dyes, but it is unable to reduce the dissolved solid content, which makes water re-use a difficult task (Shanmugasundaram, 2007).

Chemical Treatment :

Chemicals are used during wastewater treatment in an array of processes to expedite disinfection. These chemical processes, which induce chemical reactions, are called chemical unit processes, and are used alongside biological and physical cleaning processes to achieve various water standards. Chemical methods of effluent treatment include oxidation, ozonation, photo chemical and Fenton reaction.

Oxidative process :

Many dyes are effectively decolourized using chemical oxidizing agents and found to hold potential for future use in the textile industry. Many studies on usage of different oxidizing agents *i.e*, chlorination, chlorine dioxide treatment, ozonation, hydrogen peroxide with other salts, permanganate, etc. have been reported (Joshi *et. al*., 2004). But the main oxidizing agent used is hydrogen peroxide. This agent needs to be activated by some means, for example, ultraviolet light. Chemical oxidation removes the dye containing effluent by oxidation in aromatic ring cleavage of the dye molecules.

Photo chemical process :

Decolourization of dyes using UV/H_2O_2 photochemical oxidation has been investigated by several researchers. This method degrades dye molecules into carbon dioxide and water by UV treatment in the presence of H_2O_2. Degradation is caused by the production of high concentrations of hydroxyl radicals. UV light activates the destruction of H_2O_2 into two hydroxyl radicals (Fig. 2) which causes chemical oxidation of organic matter.

$$H_2O_2 \xrightarrow{UV} 2\,{}^{\bullet}OH$$

Fig. 2 : Hydroxyl radical generation through UV radiation

The rate of removal is influenced by the intensity of UV radiation, pH, dye structure and the dye bath composition. This may be set up in a batch or continuous column unit. The advantage of this process is elimination of sludge and significant reduction in foul odours. Dinarvand (2014) in their study reported that decolourization percentage Direct Blue 177 dye with UV radiation in the presence of H_2O_2 and ambient temperature of 50ºC was found to be maximum.

Ozonation :

Ozone is a more powerful oxidant than chlorine and other oxidizing agents *i.e*., O_3, Cl_2, H_2O_2 with oxidation potential of 2.07, 1.36 and 1.78, respectively and offers a mechanism for oxidizing dye wastewater without producing harmful chlorinated organics. The dosage applied to a given effluent is dependent on the total colour and residual COD to be removed. Ozone is useful for removing many toxic chemicals from wastewater, as it is capable to decompose detergents, chlorinated hydrocarbons, phenols, pesticides and aromatic hydrocarbons.

Muhammad *et al*. (2008) reported that the removal of COD, colour and BOD in case of raw textile effluent initially increased with ozonation exposure time upto 25 minutes and remained constant thereafter. This can probably be explained by the fact that some organic compounds are more susceptible to oxidation than others, while some are partially oxidized. The results revealed that dye bath effluent can be decolourized efficiently at a constant pH of 6.2 by ozonation *i.e*., 58% at 25 min exposure time.

However, in case of biotreated textile effluent, 75% COD, 95% colour and 85% BOD removal was observed at 25 min exposure time. The degree of colour removal initially increased with dose of ozone administered, but showed no appreciable decolourization thereafter, which may be due to the fact that biotreatment had already lowered the intensity of the dye bath effluent (Muhammad *et. al.*, 2008).

Advanced oxidation process (AOP) :

Advanced oxidation is a potential alternate method to decolorize and reduce recalcitrant wastewater loads from textile dyeing and finishing effluents. Advanced oxidation processes (O_3, O_3/H_2O_2, O_3/UV, UV/H_2O_2, O_3/UV/H_2O_2 and Fe_2/H_2O_2) for the degradation of non biodegradable organic contaminants in industrial effluents are attractive alternatives to conventional treatment methods. AOPs based on the generation of very reactive and oxidizing free radicals have been used with increasing interest due to their high oxidant power. Also many studies have demonstrated that AOPs are effectively removing colour and partially removing the organic content of dyestuffs.

Muhammad *et al.* (2008) mentioned that percentage removal of raw textile dye bath effluent was not appreciable, due to the fact that hydroxyl radical production in the presence of UV may require a specific pH. However, decolourization efficiency may be enhanced by applying UV/H_2O_2/O_3or increasing the concentration of H_2O_2 to ensure the availability of hydroxyl radicals. Further, in case of biotreated textile effluent, the increase in colour and COD reduction with time was not linear *i.e*., it initially increased upto 20 min exposure time and later decreased with time, which indicated that biotreated textile effluents may contain considerable amount of compounds that require a stronger oxidizing system.

Physico-chemical treatment :

Physico-chemical processes remove suspended and colloidal impurities to coagulate and flocculate reactive, disperse and vat dyes and to facilitate their removal by sedimentation. The removal is a function of entrapment within a voluminous precipitate consisting primarily of the coagulants. The coagulants mainly used include alum, lime, magnesium, ferrous, etc.

Coagulation / flocculation :

Coagulation/flocculation refers to destabilization or neutralization of negative charges contained in the wastewater by addition of coagulant applied during rapid mixing and very short contact time. Effluents contain impurities in dissolved, colloidal and suspended form. The first stage of treatment involves the precipitation and coagulation of these impurities to produce microflocs, either by pH adjustment (acid cracking) or by inorganic coagulants (Gultivalent metals) or by organic coagulants. The quantity of coagulant applied depends on the quality of water. The most commonly used coagulants are ferric chloride, ferric sulphate, aluminium sulphate, lime, etc.

Several studies have been reported on the use of different coagulants for textile wastewater treatment. It has been found that a particular coagulant is suitable for only certain dyes; for example, alum is unsatisfactory for the removal of colour generated from azoic, reactive, acid and basic dyes, but is good for treating disperse, vat and sulphur dyes. Combinations of various chemicals have been used to improve colour removal from effluent containing the more common dye types. Verma *et. al.* (2012) reported in their study that $MgCl_2$/Lime was found to be superior coagulant as compared to $FeSO_4.7H_2O$/Lime, $FeSO_4.7H_2O$/NaOH and $MgCl_2$/NaOH for treating textile wastewater containing Reactive Black 5, Congo Red and Disperse Blue dyes.

Biological treatment :

Biological treatment depicts a cheaper and environment friendly alternative for colour removal in textile effluents. Biological processes remove dissolved organics from effluent and thus reduce chemical and bio-chemical oxygen demands of the effluents. This is achieved biologically wherein bacteria/fungi are used to convert the colloidal and dissolved carbonaceous organic matter into various gases.

Aerobic treatment :

Aerobic treatment is one of the most commonly used treatment methods for wastewater generated from textile dyeing operations. Normally, this removes the biodegradable components of the effluent, for example, carbohydrates, waxes and the readily degradable auxiliary compounds, although more complex compounds such as dyes and surfactants remain as it is.

Agarry and Ajani (2011) conducted a study on 'Evaluation of microbial systems for biotreatment of textile waste effluents in Nigeria: Biodecolourization and Biodegradation of textile dye' and reported that *Pseudomonas fluorescence* demonstrated a higher per cent dye decolourization (46%) than *Pseudomonas nigificans* (41%) and *Pseudomonas gellucidium* (39%), respectively. Meanwhile, among the fungal isolates, *Aspergillus niger* showed a higher per cent dye decolourization (48%) than *Proteus morganii* (44%) and *Fusarium compacticum* (42%), respectively. Further it was found that all the isolates depicted a COD reduction between 74 and 97 per cent and a BOD reduction between 77 and 95 per cent, respectively.

Similarly, Selvam and Shanmuga (2012) in their study concluded that *Schizophyllum commune* was more efficient than *Lenzites eximia* for the treatment of azo dyes and textile dye industry effluent in both batch mode and continuous mode. The authors mentioned that the colour removal by the basidiomycetes fungi were mainly due to adsorption of the dyes to the mycelial surface and also due to metabolic breakdown. However, the batch mode treatment of textile industry effluents by *Schizophyllum commune* was more efficient when compared to continuous mode.

Anaerobic treatment :

Anaerobic treatment involves oxidation-reduction reaction with hydrogen rather than free molecular oxygen aerobic system. Anaerobic bioremediation of azo and other soluble dyes to be decolourized by breaking them into corresponding amines has been widely studied. The intentional generation of amines that are more toxic than dye are not appealing from environmental perspective. The decolourization occurs due to azo reduction but the complete mineralization does not occur. Anaerobic process usually occupies less space, treats waste upto 30,000 mg/L COD, has lower recurring costs and produces less sludge.

Conclusion :

Consumer awareness on the environmental issue is on the rise. It is the need of the day to substitute hazardous chemicals by using environment friendly methods. Thus, textile industry cannot ignore the environmental impact of the activities.

Textile wastewater treatment before discharging is of great importance in decreasing pollution load and production costs. The problem of colour in the effluent can be reduced to an extent by adopting right approach, proper work practices and waste minimization programs. The dye manufacturers may also help by producing dyes with a better fixation rate. Conventional technologies to treat textile wastewater include various combinations of biological, physical, and chemical methods, but these methods require high capital and operating costs. Till date there is no single and economically attractive treatment that can effectively decolourise dye effluents. In the past years, notable achievements were made in the use of biotechnological applications to textile effluents not only for colour removal but also for the complete degradation of dyes. Hence the need is urgent and immediate and the pressure must be maintained to evolve more effective, widely applicable and commercially viable techniques of colour removal from textile effluents.

Further, the best approach to reduce wastewater discharge is to manufacture eco-friendly products and to modify certain areas of textile processing in such a way so as to avoid toxicity as efficiently as possible.

"Better handling of textile waste and their efficient disposal will surely be an appropriate step to maintain ecological balance on earth"

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