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Wastewater Pollution from Textile Industry and its Control

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Abstract—*Textile has become a major source of income for India's economy. Textile manufacturing involves various processes like yarn fabrication, fabric production, dying/printing, finishing etc. As far as the generation of liquid waste is concerned out of the above mentioned processes dyeing/printing and finishing are of main importance. These processes are water intensive hence produces large volume of wastewater containing a wide variety of dyes, natural impurities, acids, alkalis, salts and sometimes heavy metals. Unfix dyes (5% to 50%) are one of the major environmental problem toward treatment of textile wastewater. Wide range of structurally diverse dyes has been used in this sector. Coloured textile effluent after joining any water body make the water unfit for downstream usage as well as interfere with natural activities of aquatic life. The treatment of textile processing effluents is of interest due to their toxic and aesthetic impacts on receiving water body. Several factors like the dye type, method of fabric formation (weaving or knitting) required quality of end product (degree of mercerization and finishing provided to the textile) wastewater composition etc. determine the technical and economic feasibility of each single dye removal technique.*

In the past several decades, many techniques have been developed to find an economic and efficient way to treat the textile dyeing wastewater, including physicochemical, biochemical, combined treatment processes and other emerging technologies. To treat the textile processing effluent to desired level (discharge or recycle) better understanding of different treatment methods including their merits and demerits is necessary. This literature reviews different treatment methods used in last decade.

1. INTRODUCTION

Textile now has become a major source of income and thus of great importance for India's economy. India is the second largest cotton trader after the USA (Ministry of Textile, Govt. of India). The textile waste water is rated as the most polluting among all in the industrial sectors [9] as well as this industry is one of the largest consumers of water (800–1000 m3/ton), and thus largest producers of wastewater among all industries [41]. Annual discharge of dye effluent is estimated at around 50,000 tons per year [29].The effluents typically contain many types of dyes, detergents, solvents and salts depending on the particular textile process such as scouring, bleaching, dyeing, printing, finishing, etc. These pollutants are both organic and inorganic in nature and are present in varying concentration in effluent [27].A wide range of structurally diverse dyes have been used in textile industries and therefore the effluents from these places are extremely variable in composition. Textile wastewater from dyeing and finishing processes has been a serious environmental threat for years [33]. Textile wastewater is also very high in COD concentration. Moreover, textile wastewaters exhibit low BOD to COD ratios (< 0.1) indicating their non-biodegradable nature [5]. Unfortunately in India most of the effluent from the textile industry is discharged untreated into rivers. The discharge of this type of wastewater without any treatment brings about considerable adverse impacts on the receiving water bodies crying out for an efficient treatment process.

2. POLLUTION PROBLEM IN TEXTILE INDUSTRY

2.1 Color

Presence of dyes make the water not only aesthetically objectionable but also responsible for many diseases including inter alia, nausea, hemorrhage, ulceration of the skin and mucous membrane, dermatitis and severs irritation of the skin [20]. Most of the dyes are stable and has no effect of light or oxidizing agents. They are also not easily degradable by the conventional treatment methods [15].

2.2 Dissolved Solids

Use of common salt, glauber salt etc. to increase dye uptake directly increases total dissolved solids (TDS) level in the effluent. TDS are difficult to be treated with conventional treatment systems. Disposal of high TDS bearing effluents can lead to increase in TDS of ground water and surface water. Dissolved solids in effluent may also be harmful to vegetation and restrict its use for agricultural purpose [15].

2.3 BOD (Biochemical Oxygen Demand)

Organic pollutants, which originate from organic compounds of dye stuffs, acids, sizing materials, enzymes, tallow etc. are also found in textile effluent. Such impurities are responsible for increasing the BOD value thus interfere with the biological activity of the receiving water body, especially hampering the growth of photoautotrophic organisms.

2.4 COD (Chemical Oxygen Demand)

Textile effluents are often contaminated with non-biodegradable organics termed as refractory materials. Detergents are typical example of such materials. The presence of these chemicals results in high chemical oxygen demand (COD) value of the effluent. Organic pollutants, which originate from organic compounds of dye stuffs, acids, sizing materials, enzymes, tallow etc. are also found in textile effluent. Such impurities are reflected in the analysis of bio-chemical oxygen demand (BOD) and COD. [15]. Effluent having low BOD/COD value is difficult to treat by conventional biological treatment.

2.5 Toxic Metals

There are mainly two sources of metals in textile processing effluent, either as impurity with the chemicals used during processing such as caustic soda, sodium carbonate and salts or from dye stuffs like metalized mordent dyes. For instance, caustic soda may contain mercury if produced using mercury cell processes. The metal complex dyes are mostly based on chromium [CPCB, MoEF, 2007] which has a cumulative effect, and higher possibilities for entering into the food chain [24]. The toxic effect of the dyes can be attributed to their anionic nature in the aquatic environment as they may form complexes with positively charged metal ions such as Ca^{2+}, Mg^{2+} which are essential for growth and integrity of cells thus leading to suppressed growth of photoautotrophic organism.

3. CUMULATIVE EFFECT OF POLLUTANTS ON THE RECEIVING BODY

Polluted water retards the photosynthesis capacity of the receiving water body by reducing the penetration of sunlight due to color, turbidity etc. and the presence of substitute metal and chlorine which are toxic to certain form of aquatic life. The retardation of photosynthesis results in reduced level of DO level. The organic compounds present in the effluent may also undergo gradual chemical or biological changes resulting further reduction of DO concentration. The decreased level of DO results in septic condition characterized by odor, gases, floating solids and a generally disagreeable appearance.

The inorganic material present in the textile effluent renders the water unsuitable for the use because of excess concentration of soluble salts. The inorganic chemicals even in extremely low concentration may be poisonous to fish and other aquatic organisms. Visible pollution retards the development of a community or area since it discourages camping, boating, fishing etc [32].

4. TREATABILITY STUDY OF TEXTILE EFFLUENT

4.1 Coagulation

Anil Choudhary and Deepak Ojha [8] removed Colour, COD, BOD, TSS faster than physical processes using simple chemicals such as lime (10% sol.), iron salts (5% sol.), polyelectrolyte (0.1% sol.) with the help of Jar-test. They reported a COD reduction of 60%, TSS reduction of 50%, hardness reduction of 20% at particular combination of selected chemicals and at a pH of 10 to 11. The flock Produced by iron salt with lime at pH 10 to 11 is heavier and can remove more percentage of Suspended Solids than Alum in a very short time period. Iron salt (ferrous sulphate and ferric sulphate) makes 90% treated water and 10% sludge. The Sedimentation of sludge is very fast by Iron salt than Alum. Being good oxidizing agents, the Iron salts can remove Hydrogen sulphide, hydrogen sulphate and its corresponding Odour and tastes from water. The drawback associated with this chemical treatment is 32% increase of TDS level in treated effluent due to addition of lime solution.

Selcuk [39] observed that the performance of single coagulation treatment was not satisfactory with respect to reuse of water. As compared to the ozonation process, it was found that only approximately 50– 60% color and 60% COD removal were achieved using 1000 mg/L and 1500 mg/L of ferrous sulphate (FeSO4.7H2O) and aluminum sulphate (Al2(SO4)3.18H2O) in a single coagulation treatment, respectively. Besides the low rejection of color and COD, single coagulation treatment was also found not to be a suitable treatment on textile wastewater due to high chemical sludge production.

Loan [32] observed that the removal efficiency of colour gets hardly affected by change of pH. While experimenting with coagulation/flocculation process he found that the optimum pH as 5 to 7 depending upon dye type and used aluminum sulfate Al2(SO4)3.18H2O as coagulant. The COD removal efficiencies at the optimum coagulant dosages for color removal were 81% for mixed and disperse and reactive wastewater (final COD 230 mg O2/L), and for vat wastewater 84%. For disperse and acid wastewater only 53% COD removal efficiency was found.

4.2 Chemical Oxidation

Sarina et at [36] observed very high rates of color removal during electrochemical oxidation, using Hypochlorite- more than 95% of the color was removed and COD removals greater than 97% were also observed. During treatment increase in the temperature of the dye bath from 26 to 45°C has also been observed but no significant change in pH has been reported. Operating costs for ozone were higher than for electrochemical treatment for the same level of color removal. Chemical reduction would be a very cost effective technology only if the reuse criterion is not predominant as only a portion of the color was removed by this process.

Loan [32] observed that Fenton’s reagent process as a pretreatment step was better than the O3 or O3/H2O2 process in terms of color removal and especially in terms of COD removal for highly colored waste water except for the acid dyes wastewater. With the application of Fenton‘s reagent, the coagulation and oxidation process occur simultaneously. Associated disadvantages of using Fenton’s reagent process are large amount of sludge production as by product, needs pH adjustment before discharge etc. thus economically not feasible when applied as a pre-treatment step. Fenton's reagent had the highest color removal efficiency at 400C.

Eslami et al [18] introduced electro chemical process to enhance chemical Fenton process and observed increase in the removal efficiency. He found that electrochemical Fenton process was more efficient than the chemical Fenton process and requires quite less reaction time in the degradation of textile wastewater but the operational cost was about 2 times more than that of CF process.

If metal complex dyes are present, dye solubility and charge are important factors that determine the successful removal of heavy metals. In order to maximize dye insolubility, pH control is crucial [13]. Unlike conventional methods this method does not produces any sludge. In this process, the recovery of metals or chemicals is easily carried out and at the same time, the emission of gases, solid waste, and liquid effluent are minimized. This process can handle different volumes and pollution loads. Its main disadvantage is that it generates iron hydroxide sludge (from the iron electrodes in the cell), which limits its use.

4.3 Ozonation

As discussed by Lau, and Ismail [26] the ozonation process shows a higher reactive dye removal compared to Coagulation/flocculation, activated carbon and membrane filtration treatments, regardless of types of reactive dyes used. It is very effective towards oxidation of dyes and removing color, which is the main disturbing factor for water recycling in the textile industry. This observation was similar to the work carried out by Selcuk [39] where almost complete removal of color absorbances (>98%) was achieved using ozonation in short ozone contact time. Furthermore, to increase the efficiency of the ozonation treatment system for both COD and colour removal [40] reported that much better results were obtained using a combined coagulation–precipitation /ozonation treatment instead of using a single-stage treatment system.

4.4 Adsorption

The adsorption on activated carbon without pretreatment is impossible because the suspended solids rapidly clog the filter [25]. This procedure is therefore only feasible in combination with flocculation–decantation treatment or a biological treatment. While working with granular activated carbon Sarina et at [36] observed a linear relationship between color removal and GAC dose, increase in GAC dose resulted in decrease in colour. A maximum color removal of 86% and COD removals of 70% were observed at a GAC dose of 20 g/L. These GAC doses were very high and outside the range of doses that would be economically feasible. Both the high cost of treatment and generation of spent GAC make adsorption unattractive as a reuse alternative.

Debabrata Mazumder [17] treated homogenized textile waste water firstly by chemical oxidation/coagulation-flocculation and then by adsorption using commercially available bleaching powder and crushed burnt coal (C.B.C.). Coagulation-flocculation showed a low COD removal capacity of about 50% and about 65% of color removal at the optimum dosage of 2%. By increasing the bleaching powder dose to 10% better removal efficiency was observed as COD and color removal of about 85% and 97% respectively. At 10 % CBC dosage and contact period of 90 minute showed no residual color. A nominal adjustment of pH of the effluent is required to meet the discharge standard even after the adsorption as a second stage of treatment.

4.5 Biological Treatment

Because of the low biodegradability of most of the dyes and chemicals used in the textile industry, their biological treatment by the activated sludge process does not always achieve great success. It is remarkable that most of these dyes resist aerobic biological treatment, so adsorbents, such as bentonite clay or activated carbon, are added to biological treatment systems in order to eliminate non-biodegradable or microorganism-toxic organic substances produced by the textile industry [28, 34]. The efficiency of biological treatment was significantly enhanced when biological treatment was given to an effluent pre-treated with activated carbon. Lina et al. [28] found that Waste water treated with activated carbon appeared to be almost transparent, hence promoted the growth of the bacteria and thus the efficiency of biological treatment. Four days retention time resulted in more than 87% removal of BOD5 and 85% removal of COD where as six days retention time resulted in more than 92% removal of BOD5 and 90% removal of COD respectively. Similar result was observed by Iqbal et al. in 2007 [22].

A 25% less retention time, was achieved by biological treatment process in conjunction with chemical treatment when compared with the results of biological treatment of waste water pre-treated with activated carbon gave 88% and 86% removal of BOD and COD content respectively, whereas four days retention time resulted in 94% and 92% of BOD and COD loadings of the treatment effluent. [1, 37]. The RBC system could achieve about 90% removal of color and about 95% removal of COD under optimum operating conditions. The biofilm study concluded that a mixed culture of microorganisms ,both bacteria as well as fungi was responsible for the treatment of textile industry wastewater and the recovery of the RBC system could be very fast in case of any shock-loading occurred.

The textile process houses which undertake chemical processing do not have much organic load in their effluents. In such cases, the recent trend is to set up an activated adsorption system or an ozonation unit instead of biological treatment process [15]

4.6 MEMBRANE PROCESSES

Among these methods, membrane processes appear to be the most promising method for textile water reuse [16, 23, 30].

Microfiltration (MF) is suitable for the removal of colloidal [31, 30] dyes whereas ultrafiltration (UF) and reverse osmosis remove particles and macromolecules

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

Ultrafiltration enables elimination of macromolecules and particles, but the elimination of polluting substances, such as dyes, is never complete (it is only between 31% and 76%) [42]. Even in the best of cases, the quality of the treated wastewater does not permit its reuse for sensitive processes, such as dyeing of textile. Rott and Minke [35] emphasize that 40% of the water treated by ultrafiltration can be recycled to feed processes termed “minor” in the textile industry (rinsing, washing) in which salinity is not a problem. Ultrafiltration can only be used as a pretreatment for reverse osmosis [14] or in combination with a biological reactor.

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 [13].

Microfiltration is suitable for treating dye baths containing pigment dyes [3], as well as for subsequent rinsing baths. The chemicals used in dye bath, which are not filtered by microfiltration, will remain in the bath. Microfiltration can also be used as a pretreatment for nanofiltration or reverse osmosis.

4.7 Photocatalytic Degradation

Amrit et al [7] conducted photocatalytic degradation of Direct Yellow 12 dye using UV/TiO_2 in a shallow pond slurry reactor. COD analysis of the dye under optimum conditions showed 94% reduction in COD after 2.5 h and complete decolourisation as determined by UV–vis analysis was achieved in 1.5 h.

Abdelkahhar et al in [6] also conducted photocatalytic degradation of selected azo dye in water over a newly deposited titanium dioxide. He concluded that pH played an important role in dye adsorption. A direct correlation between pH, adsorption and rate of degradation was found. The discoloration and complete mineralization of the two dyes could be achieved. The by-products of the photocatalytic degradation were biodegradable and non-toxic for bacteria from activated sludge. These results suggest that UV-irradiated TiO_2 coated on non-woven paper may be considered as an adequate process for the discoloration and detoxification of the treatment of diluted colored textile wastewater.

Alinsafi et al [2] observed decolourization of textile wastewater was in the range of 21–74%, with COD removal rate between 0.2 and 0.9 g COD/h/m^2, under solar irradiation with TiO_2 particles as photocatalys. According to his observation these results are strongly dependent upon the fine chemical structure of the dyes and the global composition of the wastewater but no pH adjustment is necessary and wastewater at high pH can be treated directly after suspended solids removal.

4.8 Constructed Wetland

Arda Yalcuk, Gamze Dogdu, [4] tried to analyze the treatability of constructed wetland using Typha angustifolia and Canna indica at room temparature. By using constructed wetland on 40th day from commencement of the treatment they observed 83.2% COD removal at Typha angustifolia reactor with averagely fed of 250 mg/l of diluted Yellow 2G solution.

Bulc and Ojstrsek [11] observed COD removed up to 84 % in the pilot-scale constructed wetland mostly owing to the filtration, sedimentation, and adsorption of various dyestuffs and auxiliaries, Baughman et al. [10] reported 20–34% efficiency for 50 mg/l COD inflow. S.A. Ong et al. [38] stated in their studies that COD removal values as 79.82 and 78% for the non-aerated reactors. However, emergent plants can contribute to wastewater treatment processes in a number of ways, such as settlement of suspended solids, providing surface area for microorganisms and providing oxygen release [12, 25].

Arda Yalcuk, Gamze Dogdu [4] observed a very high colour removal by using Canna and Typha reactors as 98.24±1.88 %, 98.58±2.49 % after treatment. Plants effects were extremely important factor for the color removal compared to the control reactor and color was treated the most effectively by the system. They concluded that Typha angustifolia was more durable and it achieved high treatment performance than Canna indica to treat synthetic acid yellow 2G azo dye. In 2008 Slovenian researchers T.G. Bulc, A. Ojstr˘sek [11] while working with constructed wetland observed color reduction, up to 70% in the CW model and up to 90% in the pilot CW using filtering medium as sand and gravel with plant as Phragmites australis in pilot scale CW. They also observed 66 % BOD removal, 52% total nitrogen removal and 93% TSS removal. The difference in efficiency depends on type of vegetation. Localize coco yam (arbee) plant performed 7.6% better than traditional cattail millet (bajra). Zurita et al. demonstrated the use of ornamental species for waste water treatment in Mexico. These economic plans were able to survive for more than 12 months and also reduced BOD up to 80%, ammonium ion (NH_4) up to 72.2%, total phosphorous (P) up to 50%, and TSS up to 82 %. After being used for treating industrial effluent these plants can be sold to open market for decorative purposes.

4.9 Solar Still

Suresh et al tried to treat dye rich waste water using solar still and got appreciable results. They found pH reduction of 8 to 7, TDS reduction of 98%, Cod reduction of 95%, electrical conductivity reduction as 97%, sodium reduction as 99%, potassium reduction as 38%,, calcium reduction as 97% and magnesium reduction as 90% with the treated water characteristic as pH (7.0), TDS (55.1 mg/l), COD (30.0 mg/l), electrical conductivity (0.11 mho/cm), sodium (4.4 mg/l), potassium (16.0 mg/l), calcium (5.0 mg/l), magnesium (18.0 mg/l) and zinc (4.9 mg/l). They observed an increase in zinc concentration (from 0.21 mg/L to 4.9 mg/L) in the final treated water due to the using of galvanized iron (GI) sheet as the basin. They observed the zinc concentration in the treated water as 4.9 mg/l which was within the potable standard (5.0 mg/l). Thus from their study they concluded that solar still may be considered as the ideal tool for treating the dye effluents and it can feasibly replace RO system. The main advantage of solar still is that contrary to the performance of an RO system which yields partial recovery of water and a heavily concentrated effluent reject solar device yields almost full recovery of water and no effluent reject.

Reverse osmosis effectively decreases salinity, but may be too expensive for underdeveloped regions. Solar stills provide a safe, low cost method for clean water production in sunny, rural locations. Several researchers have estimated the cost of solar still water production. Estimates range from $2.40 to $20 per cubic meter [19]. Solar distillation avoids the high initial investment and high energy and maintenance costs of RO. With proper engineering, materials sourcing, and quality construction, a solar still has the capability of delivering the same quality of water as RO without the high energy costs [21].

4.10 Combined Processes

In 2010 Xujie Lu et al [43] showed that use of pilot plant with biological treatment systems and membrane technology appreciable amount of colour, COD and turbidity can be removed. Average removal efficiencies of colour COD and turbidity can be up to 94.5%, 93% and 92.9%.

Processes that combine membrane with conventional treatment process/membrane process have been widely applied to achieve lower capital cost and higher productivity. However, fouling is often the main problem of membrane system for complex textile manufacturing wastewater. Dyes are the components which mainly contribute to colloidal fouling layer onto the membrane surface [26].

The combined treatment of ozonation and subsequent biological degradation with a biofilm to reduce the color from textile wastewater was studied by Souza *et al.* [46]. Results revealed that ozonation of Remazol Black B was effective and the color removal could reach as high as 96%. The subsequent biological treatment was capable of reducing the toxicity of the resulting solution after ozonation.

The integrated sequential photocatalytic oxidation and membrane filtration were used for the treatment of dyestuff effluent [44]. The combined effects of both heterogeneous photocatalytic oxidation and reverse osmosis membrane leads to complete decolorization of the synthetic dyestuff effluent as well as 90% reduction of initial organic content. In the year 2008, the photocatalytic and combined anaerobic-photocatalytic treatment of textiles dyes was studied [45]. Results demonstrated that photocatalysis was able to remove 90% of color from crude as well as autoxidized chemically reduced dye solution.

5. CONCLUSION

From the above study it is clear that the complex textile processing waste water cannot be treated efficiently by any single treatment method. Combination of physio-chemical, biological and advance treatment methods may be adopted depending upon the composition of the raw waste water as well as the end use of the treated water.

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