A REVIEW OF THE TEXTILE INDUSTRIES WASTE WATER TREATMENT METHODOLOGIES

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Abstract : Textiles is one of the largest industries in the world. The textile industry generates huge quantities of complex chemical substances as a part of unused materials including dyes in the form of wastewater during various stages of textile manufacturing and processing. The textile industry effluents which are discharged are treated with various physical and chemical treatments such as coagulation, flocculation, ozonation and biological treatment for the removal of nitrogen, phosphorous, organics and metal traces. This paper reviews the various treatment methodologies for textile wastewater with the advantages and disadvantages of the same.

Introduction

Textiles being the largest industries in the world, is one of the industries to cater to the basic needs of humans, and has been rapidly growing, more so in the developing countries. Different types of fibres that constitute the textile industry are cellulosic either from natural sources or regenerated, protein fibres that are mostly animal derivatives and the manmade fibres that are synthesized. Each of these fibres require different class of dyes to color them. The cellulosic fibres like cotton, viscose etc. have affinity to direct dyes, indigo dyes, reactive and naphthol dyes. Protein fibres are good to dye with acid dyes. Manmade fibres have affinity to disperse dyes. Basic and direct dyes are also used here. In the process of producing textiles and in the application of color on them, the textile industry gets chemically intensive and hence the major polluter of water. The textile industry generates huge quantities of complex chemical substances as a part of unused materials including dyes in the form of wastewater during various stages of textile manufacturing and processing. To produce 1kg of textile about 200L of water is consumed [1]. The chemicals present in the waste water cause harm to both human health and the environment. They block the sunlight passage through the water, hamper photosynthesis, increase the biological oxygen demand and affect the aquatic life. The direct discharge of this waste water into the environment affect its ecological status by causing various undesirable changes. This has a high importance in terms of its environmental bearing, since it consumes considerably high quantity of water and produces highly polluted wastewater in large amounts.

The textile industries are required to control their discharges and have effluent treatment plants for environment protection. To protect the environment from the harmful effect of the waste generated, the ministry of Environment, Government of India has set standards for the wastewater and other wastes which are discharged into the environment after treatment. To ensure that the wastes meet the norms set by the Government, all the textile mills adopt various processes and technologies available in this regard. It is increasingly important in today's advanced way of life, to conserve the natural resources and the environment for the needs of the present and the future generations and economy.

The waste water is the primary and the most polluting component of the textile industry's effluent. The conventional techniques adopted to treat the wastewater are physical, chemical and biological methods.

1. Physical – Sedimentation (Clarification), screening, aeration, Filtration, Flotation and skimming, degasification, Equalization.

2. Chemical – Chlorination, Ozonation, Neutralization, Coagulation, Adsorption, Ion exchange

3. Biological

   a. Aerobic – Activated sludge treatment methods, Trickling filtration, oxidation, ponds, lagoons, aerobic digestion

   b. Anaerobic – Anaerobic digestion, septic tanks, Lagoons

The treatment process can be sequenced as below:

   I. Primary treatment – Removal of suspended solids, oil, grit etc.

   II. Secondary treatment – Use of microorganisms in either aerobic or anaerobic condition for the reduction of the BOD, removal of color, oil and phenol.

   III. Tertiary treatment – Use of electro dialysis, ion exchange and reverse osmosis for the final removal and purification of the wastewater

The textile industry effluents which are discharged are treated with various physical and chemical treatments such as coagulation, flocculation, ozonation and biological treatment for the removal of nitrogen, phosphorous, organics and metal traces. The disadvantages of the physic – chemical processes are the formation of sludge, disposal of sludge and the space needed. The disadvantages of the biological processes are the presence of the toxic heavy metals which hamper the growth of microorganisms, most of the dye stuff used are non-biodegradable in nature and the time requirement for the treatment is more [1].

PRIMARY TREATMENT PROCESS

The first step is the removal of suspended solids, excessive quantities of oil, grease and gritty materials. The effluent is first screened for coarse suspended materials such as yarns, lint, pieces of fabrics and rags using bar screens and fine screens [2]. The screened effluents then undergo settling for the removal of the suspended particles. The floating particles are removed by mechanical scraping systems. Ultrafiltration using modified poly vinylidene fluoride membrane which has 60% of styrene-acrylonitrile in content and 40% poly vinylidene fluoride with a porous top layer and a sub-layer with a number of pores. The color removal and COD reduction is moderate accompanied by reduced membrane fouling for separation and purification of dye solutions [3].

The treatment by ultrafiltration and /or nano filtration nullify some of the limitations of the membrane process such as fouling, pore blocking and cake formation and enables water reuse [4]. The nano filtration techniques achieve a sharp reduction in COD along with the dyes removal from the permeate [5]. The cross flow nano filtration with the help of a thin film composite polysulfone membrane working at low pressures, relatively high fluxes are obtained, with an average dye rejection of 98% and NaCI rejections of less than 14%. Thus, a high quality of reusable water is recovered [6].

The electro flotation technology is effective in removing colloidal particles, oil & grease, as well as organic pollutants with better performance than either dissolved air flotation, sedimentation, impeller flotation [7]. Electro deposition is effective in recovery of heavy metals from wastewater streams [7].

To reduce the acidic contents of the effluents neutralization is done. Sulphuric acid and boiler flue gas are the most commonly used chemicals to alter the pH. A pH value of 5-9 is considered ideal for the treatment process [8] (Babu R et al., 2007). The screening is followed by sedimentation which makes use of gravity to settle the particles. Simple sedimentation is not effective and is also space consuming process. Coagulation should be carried out which is advantageous, with ferrous sulphate, lime, alum, ferric sulphate or ferric chloride [9]. A combination of fluidized biofilm with chemical coagulation and electrochemical oxidation effectively decreases the pollutant loading on the post treatment process [10].

Electrocoagulation with aluminum, iron or the hybrid Al/Fe electrodes are suitable for water production or wastewater treatment [7]. Utilization of plant-based coagulants are comparable to their chemical counterparts in terms of efficiency. This represents important progress in sustainable environmental technology as they are renewable resources and their application is directly related to the improvement of quality of life in the ecosystem [11]. The use of Ipomoea dasysperma seed gums is effective for decolourization of direct dye and in combination with conventional coagulants like polyaluminum chloride their coagulation efficiency is well extended even for reactive and acid dyes [12].

Some novel pre-hydrolyzed coagulants such as a polyaluminum chloride, polyaluminum ferric chloride, polyferrous sulphate and polyferrous sulphate and polyferric chloride have been found to be more effective for decolourisation of the waste water. Use of natural coagulants for treatment has also been emphasized and encouraged as the viable alternative because of their eco-friendly nature. Synthetic metallic salts as well as synthetic and natural polymers from different origins have also been used for the removal of textile colors. [13].

For the specific removal of vat dye and reactive black, the application if a food grade polysaccharide namely Plantago psyllium mucilage shows that the flocculation efficiency is sensitive to pH when pure aqueous solutions of dyes are used, but it is relatively unaffected by pH change when salts are added to the dye solutions. The results show that the mucilage is more effective for removal of solubilized vat dye than for reactive black [14].

Some of the disadvantage with flocculation system are that they are in a risk of getting short-circuited and the floc formation in the system is difficult to control. Care should be taken that the sludge disposed from the bottom of the system would not suspend the solids into the system again [1].

SECONDARY TREATMENT PROCESS

Organic matter is a source of energy and nutrients for aerobic bacteria. They oxidize organic matter to from CO2 and water degrade nitrogenous organic matter into ammonia. Aerated lagoons, trickling filter and activated sludge systems are among the aerobic system used in the secondary treatment. Anaerobic treatment is mainly used to stabilize the sludge thus generated [2].

Aerated lagoons are one of the commonly used biological treatment process. This consists of a large holding tank lined rubber or polythene and the effluent from the primary treatment is aerated for about 2-6 days and the formed sludge is removed. The BOD removal efficiency is up to 99% and the phosphorous removal is 15-25%. The nitrification of ammonia is also found to occur in aerated lagoons. The major disadvantage of this technique is the large amount of space it occupies and the risk of bacterial contamination in the lagoons [2]. The removal of heavy metals such as Pb, Cd, Zn, Cu and Cr by using duckweed and algae ponds as a polishing step was found to not be very suitable [15].

Trickling filters are another common method of secondary treatment that mostly operates under aerobic conditions. The effluent for the primary treatment is trickled or sprayed over the filter. The filter usually consists of a rectangular or circular bed of coal, gravel, poly Vinyl chloride (PVC), broken stones or synthetic resins [16]. A gelatinous film made up of microorganisms, is formed on the surface of the filter medium. These organisms help in the oxidation of organic matter in the effluent to carbon dioxide and water [17].

The microaerophilic aerobic sequential batch reactor for treatment of azo dyes help the facultative microorganisms decolorize azo dyes and total biodegradation occurs under aerated conditions resulting in 92.84% initial COD reduction along with 99.0% decolourization [18].

Trickling filters do not require huge space, and therefore are advantageous as compared to the aerated lagoons. However, their disadvantage is the high capital cost and odor emission [16].

Aerobic activated sludge process is the most commonly one. It involves a regular aeration of the effluent inside a tank allowing the aerobic bacteria to metabolize the soluble and suspended organic matters. A part of the organic matter is oxidized into CO2 and the rest are synthesized into new microbial cells. The effluent and the sludge generated from this process are separated using sedimentation; some of the sludge is returned to the tank as a source of microbes. A BOD removal efficiency of 90-95% can be achieved from this process, but is time consuming. Sludge formed as a result of primary and secondary treatment processes pose a major disposal problem. They cause environmental problems when released untreated as they consist of microbes and organic substances. Treatment of sludge is carried out both, aerobically and anaerobically by bacteria. Aerobic treatment involves the presence of air and aerobic bacteria which convert the sludge into carbon dioxide biomass and water.

The recycled alum sludge (RAS) is an efficient way of removing hydrophobic dye, while simultaneously reducing the fresh alum dosage. This process is not recommended for the removal of hydrophilic dyes, since the high solubility characteristics of such dyes may cause deterioration in the water quality during recycling [19].

For aerobically decolorizing and degrading the reactive azo dyes which generally are deficient in carbon content, starch is the best source of carbon [20]. Anaerobic treatment involves the absence of air and the presence of anaerobic bacteria, which degrade the sludge into biomass, methane and carbon dioxide [1]. The removal of water –soluble color from textile wastewater using whole bacterial cells are also suitable [21].

The conventional biological methods cannot be used for complete treatment of the effluent due to the increasing presence of molecules. Due to this, introduction of newer technologies such as cavitation, photo catalytic oxidation, Fenton's chemistry (advanced oxidation process), ozonation and use of hydrogen peroxide (chemical oxidation technologies) to degrade these refractory molecules into smaller molecules, which can be further oxidized by biological methods, are imperative [22].

TERTIARY TREATMENT

There are several technologies used in tertiary treatments including electro dialysis, reverse osmosis and ion exchange process. Electrolytic precipitation of textile effluents is the process of passing electric current through the textile effluents using electrodes. As a result of electro chemical reactions, the dissolved metal ions combine with finely dispersed particles in the solutions, forming heavier metal ions that precipitate and can be removed later. One of the disadvantage is that a high contact time is required between the cathode and the effluent [2].

Reverse osmosis is a process which uses membranes that can remove total dissolved solids. Electro dialysis another process that uses membranes that can separate the dissolved salts. The ion exchange process involves the passage of effluents through the beds of ion exchange resins which are either cationic or anionic. The chemical coagulation treatment followed by ion-exchange methods are quite effective with a maximum COD reduction of about 81.3% at 300mg/l of coagulant whereas electrocoagulation process, maximum COD removal is 92.31% [23]. Photo catalytic degradation is another method by which a wide range of dyes can be decolorized depending on their molecular structure.

Adsorption is also found to be effective in removal of color. The effectiveness of orange peel as an adsorbent in the removal of acid violet 17 (acid dye) with a maximum removal of 87% at pH 2.0 for an adsorbent dose of 600 mg/50 ml of 10mg/L dye concentration. Adsorption increases with increase in pH [24]. The effectiveness of adsorption using Indian Rosewood (Dalbergia sissoo) sawdust, pretreated with formaldehyde and sulphuric acid, for the removal of dye methylene blue shows that with the increase in the amount of the adsorbent, the percentage of dye removal increases accordingly. Higher adsorption percentages are observed at lower concentrations of methylene blue. Sulphuric acid treated sawdust or formaldehyde

ISSN 2229-5518

treated sawdust of Indian Rosewood are attractive options for dye removal from dilute industrial effluents [25].

The use of fly ash which is a major pollutant generated in coal-based thermal power plants as the adsorbent in treating the dye solutions of methylene blue or Congo red yields comparable results obtained by using activated carbon. The first-order adsorption rate constants decrease with temperature [26].

The use of polymer carbon composite membrane system removes effectively the salts dissolved in the dye wastewater and the TDS removal efficiency increases with decreasing flow rate of the wastewater [27]. The methylene blue adsorption on commercial activated carbon (CAC) and indigenously prepared activated carbons from bamboo dust, coconut shell, groundnut shell, rice husk and straw indicate that such carbons can be employed as low cost alternatives to commercial activated carbon in the treatment for the removal of color and dyes [28]. The use of activated carbon prepared from the coconut tree sawdust aids the removal of color, chemical oxygen demand (COD), biological oxygen demand (BOD), total solids and total hardness which increased with increase in carbon dose. The use of carbon is economical, since sawdust is a waste product and available in large quantities, especially in India [29].

The materials that are available in nature that have little or no use being used as low cost adsorbents for treatment of wastewater is seen as a growing approach [30].

The removal of synthetic dyes from wastewaters by adsorption on various sorbents, chemical decomposition by oxidation, photo degradation and microbiological decoloration, employing activated sludge, pure cultures and microbe consortiums are effective [31]. Thermal evaporation using sodium per sulfate also has good oxidizing potential [2].

The decolourisation and removal of textile dyes by using potato (Solanum tuberosum) soluble and immobilized polyphenol oxidase results in remarkable loss of total organic carbon [32]. The peroxidases of immobilized bitter gourd (Momordica charantia) can remove remarkably high concentrations of color from the effluent [33].

ADVANCED OXIDATION PROCESS (AOP)

The mechanism of AOP is the production of OH radicals which are capable of destroying components that are hard to be oxidized. Generation of OH radicals are generally accelerated by the combinations of H2 O2, UV, O3, TiO2, Fe2+, electron beam irradiation and ultra sound.

AOPs are classified under chemical, photochemical, catalytic, photo catalytic, mechanical and electrical processes. Generally these processes are found to reduce 70-80% of COD when compared to 30-45% reduction in the biological treatment [1].

The review of the electrochemical technologies in wastewater treatment show that, electro oxidation is finding its application in wastewater treatment in combination with other technologies [7].

The depletion of Cl- ion concentration and the COD removal is comparatively high in the presence of graphite electrode as against the aluminum electrodes in the electrocoagulation and electro oxidation techniques for the synthetic polyester fabric industry effluent [34].

Use of mesoporous activated carbon as a heterogeneous catalyst, in the homogeneous and heterogeneous Fenton system yield enhanced rate of oxidation reaction, minimum sludge production, low electrical energy input and the COD removal is in excess as compared to the homogeneous Fenton oxidation by 30% [35].

The optimization of ozone treatment shows that the treatment time plays a major role in the decolouration and COD removal of the acid dye effluent [36]. ZnO as an effective semiconductor catalyst for photo catalytic degradation of dyes result in substantial reduction of COD and removal of color [37].

By using a combined process consisting of biological pretreatment, chemical coagulation and electrochemical oxidation the COD and color reduction by 98.5% [38] was achieved. In the decolourisation of commercially important azo dyes under anaerobic conditions, with no inhibition of methanogenesis with dye concentrations of up to 400 mg/l, color removal of >99% , COD removal of up to 95% had been observed [39].

The electrochemical method to treat the organic pollutants reduces the COD substantially and due to the strong oxidation potential treats water to be effectively reused for dyeing application [40].

The recycling of wastewaters of textile dyeing industries using advanced treatment technology suggest that the dye bath water on treatment with sand, nano filtrations and then with multi effect evaporator / solar evaporation pond followed by treatment in a sequence of physicochemical and biological unit processes into two stages reverse osmosis membrane systems results in the removal of total dissolved solids, chemical oxygen demand, chloride and sodium were found to be in the range of 80-97%, 91-97%, 76-97% and 96% respectively [41].

The solar light induced degradation of textile dye reactive blue 4 is a viable technique for the color removal, since the dye gets totally mineralized when irradiated with TiO_2 photo catalyst [42].

Hybrid methods are majorly a combination of advanced oxidation processes viz Ultrasound / H_2O_2 or ozone, UV /H_2O_2 or ozone, Ozone / H_2O_2, sono-photochemical oxidation, Photo-Fenton processes, catalytic advanced oxidation processes, use of advanced oxidation processes in conjunction with biological oxidation and sono chemical degradation followed by wet air oxidation [22].

The bioremediation concepts for treatment of synthetic dye containing wastewater show that increasing number of microorganisms have the ability to decolorize and degrade artificial dyes and novel bioremediation approaches for treatment of dye bearing wastewaters. The biotechnological applications are not only for color removal but also for the complete mineralization of dyes. Different microorganisms such as aerobic and anaerobic bacteria, fungi and actinomycetes catalyze dye decolourisation with good efficiencies [43].

CONCLUSIONS:

The textile industry is a major polluter of fresh and ground water, thereby rendering the effluent water mixed with toxic chemicals. The effluent hence is treated by various methods such as physical, chemical and biological methods. The removal of color from the textile wastewater by means of cheaper and environmental friendly technologies is still a major challenge. The removal of color poses to be the subject of maximum scope with varied techniques to eliminate the color components.

The physic-chemical means for the removal of dyes and pollutants are very costly and the concentrated sludge disposal is an issue. For a high degree of efficiency and good economics none of the individual methods of wastewater treatment are suitable and hence hybrid methods are imperative.

The materials available in nature that have little or no use being used as low-cost adsorbents for treatment of wastewater is seen as a growing approach. Novel bioremediation processes and increasing number of microorganisms have the ability to decolorize and degrade the dyes. The advanced oxidation process is gaining attention in the recent days due to its ability to treat almost all the solid components in the textile effluent. This process is also found to be much more efficient in the reduction of COD as compared to the biological processes.

The studies on sustainability of wastewater treatment technologies and the development of a set of indicators that incorporate environmental, societal and economic sustainability are an increasing need, taking into consideration the global warming, resource shrinkage and global climate changes. While selection of a set of indicators is dependent on the geographic and demographic context of a particular community, the degree of sustainability of each technology is definitely the way forward.

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