An overview of treatments for the removal of textile dyes

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ABSTRACT

Wastewater discharged from industries contains contaminants including dyes. Removal of dyes from industrial wastes using different methods has been reviewed. Biological treatment requires large area and also less tractability in operation. Chemical treatment is not cost effective. Adsorption process is simple and effective manner. Activated carbon is found to be more effective because of high specific surface area, high adsorption capacity. Activated carbon costs more and efforts have been made for producing it using several waste products.
Keywords: Adsorption, Biological, Chemical, Dyes, Pollutants

INTRODUCTION

Nowadays, the public has become more sensitive towards the protection of the environment and general awareness has now increased about the potential adverse effects of industrial effluents contaminate with various pollutants, including dyes on the environment (SartlaYadav, 2011).Dyes are mainly engaged in the Textile, Food, and Pharmaceutical, Cosmetics, plastics, Photographic and Paper industries. Though the rapid industrialization is the best way to achieve economic growth, it affects human health directly or indirectly by escaping wastes into water bodies. Unfortunately, most of dyes escape into conventional wastewater treatment process. Although dye effluent escape into water bodies from various sources, Textile plant is classified as the most polluting industrial sector. It is noteworthy that some dyes are highly toxic, Mutagenic, And Carcinogenic and also decrease light penetration & photosynthetic activity, causing oxygen deficiency and limiting downstream beneficial uses such as Recreation, drinking water & irrigation (Mohammed Bassim Alqaragully, 2014). Environmental legislation obliges industries to eliminate colour from their dye containing effluents before disposal into the water. Technologies for colour removal of dye can be divided into three categories: Biological, Chemical and Physical methods (Robinson, 2001).

Biological methods: Biological treatment is often the most economical alternative when compared with other physical and chemical processes. Methods like fungal decolourization, microbial decolourization, adsorption by (living or dead) microbial biomass and bioremediation systems are commonly applied to the treatment of industrial emission because many microorganisms such as bacteria, yeast, algae, and fungi are able to accumulate and degrade different dyes (McMullan, 2001 and Fu and Viraraghavan, 2001). But biological treatment requires large area and this method is unsatisfactory in colour elimination with current biodegradation processes (Robinson, 2001). Based on different oxygen demand, biological treatment methods are classified into aerobic and anaerobic treatment. Aerobic biological treatment is conventional biological treatment because of high efficiency and wide application. Biological process is cheaper than other methods. When compared to chemical methods, for biological process investment cost is 5-20 times less and operating costs are 3-10 times less than chemical methods. (Rajendra Ramasamy, 2012).

Selvam.K et al., (2012) explored biological treatment of azo dyes & textile industry effluent by newly isolated White rot fungi *schizophyllum commune and lenziteseximia*. Congo red, Methyl orange, Erichrome black-T were decolourized by these fungi. Decolourization in textile dye effluent was observed that 76.15% & 55.92% during batch and continuous mode respectively on 5th day by using *schizophyllum commune.* Decolourization in textile dye effluent was observed that 75.23% & 54.60% during batch and continuous mode respectively on 5th day by using *lenziteseximia.* The experiment results show that *schizophyllum commune* is used efficiently in colour removal of textile dyes.

Mane U.V et al., (2008) found that the isolated Actinomycete, *Streptomyces krainskii*, SUK -5 decolorize and degrade textile dye Reactive blue–59. Induction in the activity of Lignin Peroxidase and NADH-DCIP Reductase and MR reductase represents their role in degradation. The biodegradation was observed by TLC, UV vis spectroscopy, FTIR and GCMS analysis. Microbial and phytotoxicity of the product were studied.

Chemical methods: Chemical methods include coagulation or flocculation combined with floatation and filtration, precipitation, electro floatation, electro kinetic coagulation, conventional oxidation methods by oxidizing agents such as ozone, irradiation or electrochemical processes. Though the dyes are removed completely by this process, it is so expensive and also accumulation of concentrated sludge creates a disposal problem. Excessive chemical use generates secondary pollution problem. Coagulation includes the use of suitable chemicals, through a chemical reaction, forms an insoluble end product. By this product, substances like dyes from the wastewater effluent can be removed (SaritaYadav, 2011). Generally used coagulants were alum, ferric chloride, etc. Although small colloidal particles can be removed by electro kinetic coagulation, it is not suitable for all type of dyes. Recently, new emerging techniques, known as advanced oxidation process, which are based on the generation of very powerful oxidizing agents such as hydroxyl radicals, have been applied with success for the pollutant degradation. But these methods are costly & commercially unattractive. Common problems in these methods are the high electrical energy demand and the consumption of chemical reagents.

Electrocoagulation: Nowadays, this method is widely used to decolourize dyes. It is straight forward and proficient method for the treatment of waste comprising dyes. In recent years, many investigations have been specially focussed on the use of electrocoagulation owing to increase in environmental restrictions on effluent waste water. Electrocoagulation is a process consisting of creating metallic hydroxide flocks inside the wastewater by electro dissolution of soluble anode made of Iron (Fe) or Aluminium (Al).

Hussein Hs et al., (2014) investigated the colour removal of Reactive Blue 19 from textile wastewater by electrocoagulation using iron electrodes. Effects of various such factors such as pH on dye removal, current density, electrolysis time, initial dye concentration, supporting electrolyte concentration, temperature were scrutinized. The optimum operating conditions for the effective removal was at pH 11.5, applied current density of 50mA/cm^2, electrolysis time of 20 minutes, 100mg/l dye concentration, supporting electrolyte concentration of 5g/l Nad and room temperature. Under these conditions, 99.60% of dye effectively removed.

Stercipoulous et al., (2014) investigated that electrochemical decolourization and removal of indigo carmine from Textile wastewater. Indigo carmine decolourized by electro oxidation process using Ti/pt and graphite electrodes in the presence of NaCl as supporting electrolyte. The electrical energy consumption at the applied current density of 5mAcm^{-2} with Ti/pt and graphite electrodes are 0.874 and 1.75 kWhm^{-3} of treated dye solution respectively. But efficient method for colour removal in dye solution is electrocoagulation. Through this technique, 100% colour removal is achieved in 35 and 20 minutes of electro processing at the applied current densities of 5 and 10 mA cm^{-2} with the corresponding energy consumption 0.511 & 0.825 kWh m^{-3}. The fastest and more efficient method for degradation of indigo carmine dye is electron process with Fe electrodes & supplied H_2O_2 in acidic solution. 100% dye removal was achieved in only 2 & 1 minute of electro processing at applying current densities of 0.33 & 0.66 mA cm^{-2}. Indigo carmine dye was removed upto 90% by using sonoelectrochemical process. Dye removal is higher than the electrochemical process. Process of Indigo dye removal showed first order kinetics (A.Trujillo – Ortega et al., 2013). By using integrated advanced oxidation process comprising ozone and electrocoagulation 65% colour removal, 76% turbidity removal and 37% COD reduction were attained (). Using aluminium electrodes indigo dye was removed upto 88% at initial concentration of 100mg/l, initial pH 3, operating current density of 10.7 A/m^2 and 12 min of electrolysis time (Indra Deo Mall, 2013).

Electrochemical oxidation: This method is used as an alternative treatment process for the removal of colour in dye solution. Dogan Dogan, 2012, examined electrochemical treatment of Actual Textile indigo dye effluent. This process was brought out in a Batch type divided electrolytic cell. Under constant potential using Pt cage as anode &Pt foil as cathode. Thorough colour was attained in very short time (16 minutes) at pH 2 by applying constant electrolysis voltage. Considerable percentage of COD removal (46%) was achieved by extending treatment upto 40 minutes. El Sayed Zakaria et al., (2013) investigated Removal of Indigo Carmine Dye from Synthetic Wastewater by Electrochemical Oxidation in a new cell with horizontally Oriented Electrodes. Electrochemical unit consists of Anode as pb/pbO$_2$ and Cathode as stainless steel screen. Under optimum operating conditions, complete decolourization & 88.2% COD reduction was achieved.

M.M.Ahmed et al., (2008) carried out study of electrochemical oxidation of Acid Yellow and Acid Violet assisted by transition metal Modified Kaolin. The effect of different operating conditions such as synergetic effect, current density, solution pH, electrolysis time, amount of Modified Kaolin catalyst, initial dye dosage were investigated. When initial pH was 3, current density of 40 mA/cm^2, electrolysis time 40 minutes and Modified Kaolin catalyst of 15g/l, the COD removal of dyes can reach 100%.

E.Kavitha et al., (2012) investigated electrochemical oxidation of Textile industry wastewater using DSA in tubular Reactor. This paper described the treatment of Acid green V by electrochemical oxidation. In this process Ti/RuO_2 IrO_2 tiO_2 used as Anode and Cathode and NaCl used as supporting electrolyte in a tubular flow reactor under continuous single pass processor. A set of parameters such as flow rate, current density, colour removal, cod reduction were determined by experimental methods. Sendhil J et al., (2012) studied that electrochemical oxidation reduces the color and COD of Acid green dye V textile effluent. As effluent flow rate is decreased percentage color removal increases. Energy consumption is affected by flow rate, current density and initial dye concentration.

Milica Javic et al., (2013) investigated that electrochemical oxidation is capable of destroying the chromophore groups, and full decolorization of dyes found in textile effluents can be done at short treatment times. Indirect electrochemical oxidation via hydroxyl radicals is a convenient way for the degradation and mineralization of reactive dyes and offers approach to developing new technology for removal of reactive dyes in real textile industry effluents with low energy consumption.

Photocatalytic degradation: Photo catalysis is one of the advanced oxidation processes, is a new method used to mineralize dye compounds. One of the major advantages of the photo catalytic degradation over existing technologies is that there is no further requirement for secondary disposal methods (Beydounet, 1999).

Rameshwar Amete, 2014, carried out photo catalytic degradation of Methylene Blue using Calcium Oxide. The various strictures such as effect of pH, effect of dye concentration, effect of amount of Cao, effect of light intensity were studied. Under this method COD removal also accomplished. This commentary demonstrated that photo catalysis is very effective technology for degradation of Methylene Blue dye. K.Balachandran, 2013, examined removal of Methylene Blue dye using prepared Nano titanium dioxide (Tio_2). Anatase phase TiO_2 nanoparticles were produced by solve-gel method. Lower concentration level of Methylene Blue after 5 hour reaction indicated that dye molecules were effectively decomposed. G.M.Madhu et al., (2009) examined Titanium Oxide (TiO_2) assisted Photocatalytic degradation of Methylene Blue. Complete degradation results are found at 0.1 wt% of catalyst loading at pH 2. Kinetic model for degradation of dye increases by the use of TiO2/UV/H_2O_2 system.

E.K.Kirupavasam et al., (2012) investigated photo catalytic degradation of Amidoblack-10B using Nano photo catalyst. Experimental results show that dye molecules in the presence of Ag-TiO_2 as photo catalyst effectively degraded. The photo catalytic degradation of dye showed pseudo first order kinetics. With these, effects of various constraints such as catalyst concentration, pH, and concentration of dye, H_2O_2 concentration and efficiency of colour removal were carried out.

S.A.Abo-Farha, 2010, carried out research on photo catalytic degradation of Monoazo and Diazo Dyes in wastewater on nanometer-sized TiO_2. The kinetics of the colour removal for two dyes Acid Orange 10(AO10) and diazo dye Acid Red 14(AR14) by homogeneous and heterogeneous photo catalytic degradation were described. Homogeneous and heterogeneous photo catalytic degradation occurs in the presence of UV/H_2O_2& UV/TiO_2 respectively. Using electron scavenger, photo catalytic activity was enhanced. Degradation depends upon variable factors such as initial dye concentration, pH, H_2O_2 concentration. These parameters study also carried out. It demonstrated that dye colour removal & degradation rates are proportional to number of azo & sulphonic groups present in dye molecule. Critical process parameters such that initial pH of wastewater, concentration of TiO_2 and reaction time were assessed by employing Surface Methodology.

Physical methods: Physical methods used commonly are membrane filtration processes (Nano filtration, Reverse osmosis, Electro dialysis) and Adsorption techniques.

Membrane filtration: Puasa S.W, 2012, examined the removal of C.I Reactive Black 5 and C.I Reactive Orange 16 using Micellar-enhanced ultrafiltration. Cetylpyridinium chloride was used for the MEUF. The critical micelle concentration of CPC was obtained at 0.38 g/L via conductivity method. The MEUF process was accomplished at constant operating pressure of 400 kPa. The results revealed that the highest dye removal was 78.0% and 79.2% of RB5 and RO16 respectively.

Mohammad Fadhil Abid, 2012, investigated the removal of acid red, reactive black and reactive blue dyes. Parameters such as dye concentration, pH of solution, feed temperature, dissolved salts and operating pressure on permeate flux and dye rejection were studied. With NF membrane, the final dye removal were as 93.77%, 95.67% and 97% for red, black and blue dyes, respectively. pH of solution had a positive impact on dye removal. A comparison was made between the results of dye removal in biological and membrane methods. The outcomes indicated that membrane method had higher removal efficiency with lower effective cost. Dye removal from wastewater was positively related to applied pressure, pH, TDS and dye concentration in feed solution. It was found that the order of effect of the operating variables on dye removal of NF and RO membranes was in the following sequence: C > pH > P > TDS. Results indicated that the use of NF membrane in dye removal from wastewater can be used with higher efficiency instead of the current biological method.

Adsorption: In accordance with the very abundant literature data, liquid-phase adsorption is one of the most popular methods for colour removal in dyes. Since proper design of the adsorption process will produce a high quality treated effluent. This process provides an attractive alternative for the treatment of contaminated water, especially if the sorbent is inexpensive & does not require an additional pre-treatment step before its application.

Aadil Abbas et al., (2012) compared removal of Congo red and brilliant green, by biosorption using peanut shell as biosorbent. Factors on biosorption process such as contact time, pH, agitation speed, biosorption dose, particle size was studied. Removal efficiency of Congo red was 15.09 mg/g and that of brilliant green 19.92 mg/g.

Bakhtyar Kamal Aziz et al., (2013) examined the removal of Textile dyes from waste water of Kiffry textile factory using natural clay of the area. Red clay & Yellow clay were selected from two different locations from kiffry region. Adsorption of textile dye onto the clay was studied at 25^{o}C and they were 1.2mg.g^{-1}& 0.65mg.g^{-1} for red & yellow clay respectively. Equilibrium time of adsorption was found out after 35 min and it follow the Freundlich isotherm model. The adsorption capacity of the Congo red onto the red and yellow clay was 22&12.5mg.g^{-1} respectively. The results showed that the adsorption of Congo red onto the clay has higher efficiency than textile dyes.

Hajira Tahir et al., (2013) examined that Physiochemical Modification and Characterization of Bentonite Clay and Its application for the removal of Reactive Dyes. Adsorption properties of Bentonite Clay towards Reactive Red 223 (RR 223) were studied under batch mode at various temperatures under optimizing conditions. The isotherms were well fitted in Langmuir, Freundlich & Dubinin – Radushkevich isotherm models. The optimizing conditions such as amount of adsorbent, contact time, dye concentration, temperature and pH at the point of zero charge were evaluated.

C.Umpuch et al., (2013) studied Adsorption of Organic dyes from Aqueous Solution by Surfactant Modified Corn Straw. Corn straw modified by using cationic surfactant to increase the adsorption capacity of corn straw. The adsorption isotherm well fitted in Langmuir & Freundlich models. Effect of various factor such as stay time on the removal of dye, initial dye concentration, solution pH were studied. The kinetic data were set by pseudo second order kinetic model. The adsorption of organic dyes reached the equilibrium within 180 minutes. This study shows that removal of organic dyes such as blue 20 & Yellow 21 were increased by modified corn straw.

Deshuai sun et al., (2013) investigated Adsorption of Reactive Dyes on Activated Carbon Developed from Enteromorpha Prolifera. Through Zinc chloride activation, activated carbon was prepared from Enteromorpha Prolifera. Adsorption capacities of three reactive dyes Reactive Red 23, Reactive blue 171, and Reactive blue 4 by activated carbon were 59.88, 71.94 & 131.93 mg.g^{-1} at 27^{o}c respectively. Thermodynamic study& kinetic study proposed that reaction was an endothermic reaction & second order kinetic model were well fitted to the equilibrium data. Freundlich isotherm model were fitted to the data. Effects of various parameters such as initial solution pH on dye adsorption, temperature were evaluated. Maximum dye removal efficiency of adsorption onto ACEP was obtained at the initial pH of 4.5-6.

A.K. Asia guru et al (2012) conducted various experiments for the removal of Methyl orange dye using Avacado pear seed. The adsorptive capacity of the adsorbent is increased by modification of the adsorbent by Nitric acid (HNO_3) and hydroxylamine hydrochloride ($NH_20H.HCl$).The parameter studied are concentration on sorption of dye solution, contact time, Particle size ,Biomass dosage. They compared pseudo first and second order rate equation. It obeys pseudo - second order rate equation.Freundlich and Langmuir isotherm is satisfied.

Satish Patil et al., (2011) considered the parameters such as initial MB concentration, dose of adsorbent, pH, agitation time, agitation speed, and temperature and particle size for the removal of Methylene blue dye using teak tree bark powder. They compared the study of Lagregen pseudo first order, Lagregen pseudo second order, Natarajan and Khalaf first order, Bhattacharya venkobachar first order and Elovich kinetic models. Lagregen pseudo second order model followed best than other kinetic models.

Sachin M.Kanawade et al., (2011) studied adsorption of methylene blue using activated carbon and hyacinth as adsorbents. Adsorption by water hyacinth followed Langmuir model .Adsorption using activated carbon well suits Langmuir and Freundlich isotherm models. They conducted batch experiments at three different temperaturesand Equilibrium is attained in 80 min in which activated carbon is used as adsorbent.

Table.1. Recent report on the adsorbent used for the removal of textile dyes

Type of dye	Adsorbent used	pH	Isotherms followed	References
Methylene blue	Activated carbon	5-8	Langmuir and freundlich isotherm	Sachin M.Kanawade and R.W.Gaikwad (2011)
Textile dye	Natural clay	-	Freundlich isotherm	Bhaktyar kamal aziz (2013)
Methylene blue	Teak tree bark powder	3-11	Lagregen pseudo second order model	Satish patil et al., (2011)
Reactive red 223	Bentonite clay	2-12	Langmuir, Freundlich & Dubinin – Radushkevich isotherm models	Hajira tahir et al., (2013)
Organic dyes	Surfactant Modified Corn Straw	-	Langmuir & Freundlich isotherms	C.Umpuch &B.Jutarat(2013)
Reactive dyes	Activated carbon developed from Enteromorpha Prolifera	4.5 -6.0	Freundlich isotherm and second order kinetic model	Deshuai sun et al., (2013)
Methyl orange dye	Avacado pear seed	-	Pseudo second order model, Freundlich and Langmuir isotherm	A.K. Asia guru et al., (2012)

CONCLUSION

Various biological, chemical and physical methods are adopted for the treatment of dyes which is discharged as effluent from industries. Different methods are reviewed for the removal of dyes. Adsorption is found to be most economical among all methods. Adsorption by activated carbon is most widely used method .Several attempts have been made using waste products as adsorbents for the removal of dyes.

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