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Advanced methods and current technologies for treatment of wastewater from dye industries

Ahmad Ashfaq[1], Amna Khatoon[2]

1 Assistant Professor, Civil Engineering, Faculty of Engineering & Technology, A.M.U, Aligarh - 202002, U.P., INDIA.
2 Department of Applied Chemistry, Faculty of Engineering & Technology, A.M.U,, Aligarh - 202002, U.P., INDIA.

E-mail : ahmad_ashfaq76@yahoo.com Contact No : +91-9719665211, +91-9897426638

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Abstract

Dye wastes are considered as the most problematic group of pollutants. Most of them are non-biodegradable and highly toxic in nature. Some of them are carcinogenic also like aromatic amines. This paper provides an overview of various methods for dye removal such as adsorption, ozonation, catalytic oxidation, membrane processes, biological methods and so on. The advantages and disadvantages of various methods are also discussed and their efficacies are Compared.

Key words : Non-Biodegradable, Ozonation, Catalytic Oxidation, Adsorption.

INTRODUCTION

Dyes are complex compounds with a big complicated molecular structure and toxic properties. Thus, it can affect aquatics life, human health and ecological system when dye wastewaters are extremely discharged wastewater into water sources. It eventually makes changes of ecological system and other serious pollution problems. [1]. Composition of waste water from dye and dye intermediate manufacturing is highly variable. It varies from industry to industry depending on the type of dye manufactured in a particular industry. Treatment method employed for treating waste water coming from dye industry depends on the type of chemical components present in effluent. The structure of dye is complex and influences its degradability. Various methods have been studied for treating waste water from dye industry.

Adsorption

Adsorption is an effective method for reducing the concentration of dissolved organics in an effluent [1]. There are various adsorbents being employed for decolourization of dyes. These sorbents may be categorized into organic and inorganic support. Carbon based inorganic supports have been widely used in treating waste-water from dye industry. The excellent adsorption properties of carbon-based support have been exploited for the decolorization of dyes in the industrial effluents [1].

The adsorption properties of novel biocompatible composite (chitosan-zinc oxide nanoparticle) for both Direct Blue 78 and Acid Black 26 was investigated [2, 3]. It was found that the chitosan-zinc oxide nanoparticles can be a suitable low-cost and eco-friendly adsorbent for the removal of dyes from aqueous solution. A study on the ability of chitosan to act as an adsorbent produced from waste seafood shells for the removal of five acid dyes, namely, Acid Green 25, Acid Orange 10, Acid Orange 12, Acid Red 18 and Acid Red 73 was performed [2-4].

Examples of organic supports are biogas waste slurry, orange peel, pasteurized wastewater solids, dead and pulverized macrofungus, Fomitopsis carnea etc. Chemically modified sugarcane bagasse as a potential low-cost biosorbent for dye removal was also studied [2, 5]. The sugarcane bagasse was pretreated with phosphoric acid and used for the removal of Methyl Red from aqueous solution in a batch reactor at varying dye concentration, adsorbent dosage, pH and contact time. [2, 5].

The adsorption methods, independently of the inorganic or organic character of the supports have some drawbacks. Since adsorption processes are generally not selective, the other components of the wastewater can also be adsorbed by the support and the competition among the adsorbates can influence the dye binding capacity of supports in an unpredictable manner[6]. Moreover, an adsorption process removes the synthetic dyes from wastewater by concentrating them on the surface retaining their structure practically unchanged. When the support is to be regenerated, the fate of the resulting concentrated solution of dyes presents a problem that is not satisfactorily solved. Even the mineralization of dyes on the surface of support cannot be achieved [6].

1. Photocatalytic decolorization and oxidation of synthetic dyes

Commercial dyes are designed to resist photodegradation, so the selection of optimal photocatalytic conditions for the decolorization of dyes requires considerable expertise. Because of the significant commercial and environmental interest the efficacy of a large number of catalysts and irradiation conditions has been established for the decolorization of various synthetic dyes[6].

a. Photocatalysis and oxidation with hydrogen peroxide

Hydrogen peroxide has been frequently applied to the decolorization of synthetic dyes in waters. UV irradiation combined with hydrogen peroxide treatment was used for the decolorization of the mono-azo dyes Acid Red 1 and Acid Yellow 23 [6]. Iron salt and hydrogen peroxide in combination were employed in the decolorization of waste water. The method is popularly known as Fenton's method. This method is used to treat a variety of industrial wastewaters containing toxic and nonbiodegradable organic compounds. Especially, complex wastes derived from dyes, phenols, formaldehyde, plastic additives, and rubber chemicals. The advantages of Fenton's reagent are COD and BOD reduction, color removal, organic pollutants destruction, biodegradability improvement, and toxicity reduction [6].

a. Ozonation

The reaction of dyes with ozone is important from the viewpoint of ozone fading colorants in dye wastewater treatment. Normally, using ozone alone is not always accompanied by reduction of the COD[6]. Investigated combination with other treatments such as HCO_3-, H_2O_2 or PAC. [7] Ozonation, as an effective oxidation process, has found application in the decolorization of synthetic dyes. The technique employed in the decoloration of Orange II. It was reported that ozone effectively decomposed azo dyes in textile wastewater. The decomposition rate was considerably higher at acidic pH. [6].

b. Catalytic Oxidation

It has been proven that the presence of catalysts enhances the rate of photodecomposition. The role of TiO_2 in oxidation was studied. It was shown that the photodegradation rate of azo dyes under UV irradiation considerably depends on the chemical structure in the presence of TiO_2. [6]. The efficiency of TiO_2 in removing dye waste was further supported in a study using Basic Blue 3 as the targeted pollutant [8]. In this study, optimization of photocatalytic degradation of Basic Blue 3 under UV light and TiO_2 nanoparticles in a photoreactor was investigated. Central composite design (CCD) was used for optimization and results showed that maximum decolorization was achieved at an initial dye concentration of 10 mg/L, flow rate 100 mL/min and reaction time of 120 minutes.

The investigation of the TiO_2/Ag photocatalysis system for decolorizing Procion Red MX-5B indicated that the Ag carrier from the TiO2/Ag catalyst has the oxidizing ability to degrade MX-5B color even in the absent of UV-A, however TiO_2 alone was ineffective [9].

a. Biological Treatment

The application of microorganisms for the biodegradation of synthetic dyes is an attractive and simole. The isolation of new strains or the adaptation of existing ones to the decomposition of dyes will probably increase the efficacy of bioremediation of dyes in the near future [6]. The co-removal of chromate Cr(VI) and azo dye Acid Orange 7 (AO7) using *Brevibacterium casei* under nutrient-limiting conditions was studied [10]. AO7 was used as an electron donor by the reduction enzyme of *Brevibacterium casei* for the reduction of Cr(VI). The possibility to decolorize Direct Red-80 and Mordant Blue-9 individually and in a mixture using immobilized *Phanerochaete chrysosporium* in a batch-operated rotating biological contactor (RBC) reactor was performed [11]. Experimental results showed that the decolorization efficiencies were in the range of 94100% and 7797% for individual and a mixture of dyes, respectively. The potential of *Lemna minor* (L.) for the treatment of reactive dye polluted wastewater was investigated [12]. Results showed that 59.6% maximum dye removal was found in samples containing 2.5 mg/L initial Brilliant Blue and 1 mg/L of triacontanol. In the biosorption study of acid dyes by brown alga, the reaction was found to be spontaneous and exothermic for both Acid Blue 324 (AB 324) and Acid Red (AR 337) [13]. The equilibrium data fitted well to both

Table 1. Inhibition of tested bacteria by Lactobacillus sp. isolates by agar diffusion method.

Chemical	pH	Comments
Alum	45.-7.0	For colloid coagulation and phosphate removal Basic reaction: $Al_2(SO_4)_3 + 6H_2O = 2Al(OH)_3 + 3H_2SO_4$
Lime	9.0-11.0	For colloid coagulation and phosphate removal Basic reaction: $Ca(OH)_2 + Ca(HCO_3)_2 = 2CaCO_3 + 2H_2O$ $MgCO_3 + Ca(OH)_2 = Mg(OH)_2 + CaCO_3$
$FeCl_3$, $FeCl_2$	4.0-7.0	For colloid coagulation and phosphate removal Basic reaction: $FeCl_3 + 3H_2O = Fe(OH)_3 + 3HCl$
$FeSO_4$	4.0-7.0	$FeSO_4 + 3H_2O = Fe(OH)_3 + 3H_2SO_4$

Source: Eckenfelder (2000).

Table 2. Chemical Coagulant Application

Chemical	pH	Comments
Cationic polymer	No Change	For colloid coagulation or to aid coagulation with a metal
Anionic polymer Nonionic polymer	No Change	Use as a flocculation aid to speed flocculation and settling

Source: Eckenfelder (2000).

Langmuir and Freundlich isotherms with maximum adsorption capacity 224 mg/g and 323 mg/g for AB 324 and AR 337, respectively [13].

b. Membrane technology

Membrane separation of solids from wastewater is actually a subset of filtration. They can be used to treat either the combined effluents or point source. Membrane processes are very effective, but the rate of transfer across the membranes is generally slow and pressures are high; large membrane areas are required. Membrane filtration includes ultra-filtration, dialysis, electrodialysis, reverse osmosis and so on. Reverse osmosis has been found to be applicable to industrial wastewater [14]. Membrane can be helpful in areas such as color removal, BOD reduction, salt reduction, polyvinyl acetate (PVA) recovery, and latex recovery [15]. The four common types of membrane namely: microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO). The principle for the different separation systems depends on the pore size of the membrane and the size of the particle that is to be separated [1].

c. Chemical Coagulation

Coagulation is employed for the removal of pollutants in suspended or colloidal form. Various chemicals was used to eliminate compounds present in wastewater from dye manufacturing industry such as alum, lime, ferric sulfate, ferric chloride, Polyaluminium chloride(PACl), polymer, etc. Chemicals used for coagulation in water or wastewater treatment not only should be cost effective for coagulating impurities but should not leave toxic or other undesirable residues in the water. The chemical coagulant application is presented in Table 1 and 2 [1].

CONCLUSIONS

The best solution in minimizing pollution load and production cost lies in the efficient use of resources and reduction of waste at the source. 10-20% of textile dyes are lost during the dyeing process, and 2-20% is discharged directly. Preventing this loss can substantially minimize the pollution load and also reduces the production cost. Moreover, the strategic, comprehensive, preventive measures and advanced production technology can be used to improve the material and energy utilization. Efficient and adequate use of raw material can reduce waste generation as well as prevents the excessive use of resources and thus facilitates sustainable development.

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