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Comparative decolorization of dyes in textile wastewater using biological and chemical treatment

Huma Hayat, Qaisar Mahmood *, Arshid Pervez, Zulfiqar Ahmad Bhatti, Shams Ali Baig

Department of Environmental Sciences, COMSATS Institute of Information Technology, Abbottabad 22060, Pakistan

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ABSTRACT

Textile wastewater (TW) is one of the most hazardous wastewaters for the environment when discharged without any proper treatment. A comparative study was conducted to investigate the removal efficiency of color, chemical oxygen demand (COD) and turbidity from real textile industry wastewater using anaerobic IC reactor and Fenton's process with and without pH adjustment. Color, COD and turbidity removal efficiencies have been studied for 25%, 50%, 75% and 100% textile wastewater. Results demonstrated that a maximum color removal efficiency (>92%) was recorded in Fenton's process at pH 3 for 100% sample. However, maximum COD removal efficiency of 87% was observed in IC reactor for 100% sample. Thus, Fenton's reagent at pH 3 was found highly effective for color removal and IC reactor observed to be efficient for COD removal. Furthermore, Fenton's process without pH adjustment was found higher turbidity removal efficiency as compared to other treatments. Findings from this suggested that the selective treatment process could be highly promising for the decolorization of textile wastewater and can also be practically implementable.

1. Introduction

Large amount of water used in textile dyeing processes is one of the leading generators of liquid pollutants. The quantity of textile wastewater has been increasing along with the growing demand of textile products [6]. Textile wastewater is characterized by high chemical oxygen demand (COD), biological oxygen demand (BOD), alkalinity and total dissolved solids (TDS). The dyes are stable and difficult to degrade due to their complex aromatic structure and synthetic origin [24,15,16,22].

Textile industry effluents are complex, containing synthetic dyes, dispersants, bases, acids, detergents, salts, oxidants, surfactants, inhibitory compounds, grease and oil, toxicants, many other compounds salts depending on the particular textile process such as scouring, bleaching, dyeing, printing and finishing. Discharge of the colored effluent into streams and rivers results in the depletion of dissolved oxygen, causing anoxic conditions that are lethal to aquatic organisms [11,10,8,9,15,23,25]. In addition, textile industry effluent usually contains 0.6–0.8 g/L dye, but the pollution is due to the durability of the dyes [8].

Various physical, chemical and biological methods such as adsorption, photolysis, chemical precipitation, chemical oxidation and reduction, electrochemical precipitation have been employed for the removal of dyes from wastewater [24,16,23]. However, these technologies are usually not effective in color removal, or are expensive and less adaptable to wide range of dye containing wastewaters [11,10,24]. Generally, dye degradation means decolorization and mineralization of dye in textile wastewater. Decolorization represents destruction of chromophore group of the dye molecule; likewise degradation of organic compounds into CO_2 and H_2O is called mineralization [26]. The levels of decolorization and biodegradation by many investigators is determined by measuring the percentage of mineralization by BOD total organic carbon (TOC) and COD removal ratio by measuring the initial and final content [23]. Recently, Fenton reaction was efficiently utilized in wastewater treatment process for the removal of many hazardous organics from wastewater [7,27]. The traditionally accepted Fenton mechanism is represented by following equations [13].

Anaerobic treatment presents more attractive alternative as they can be developed as a renewable and clean energy sources. The anaerobic treatment is best suited for handling load fluctuations, high BOD wastewater and low energy requirement as no oxygen has to be supplied and it also has potential for energy production [25]. Fenton's oxidation has been used for treating different types of industry wastes containing toxic organic compounds such as formaldehyde, dyestuff, phenol, and can be

* Corresponding author.
E-mail address: mahmoodzju@gmail.com (Q. Mahmood).

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used for wastewaters, contaminated soils and sludges, toxicity reduction, organic pollutant destruction, BOD/COD removal and color and odor removal [28,6,22]. It has been successfully used to detoxify, decolorize and to enhance the biodegradability of textile wastewater and dyes [20,1,21].

In this study, an attempt has been made to compare anaerobic (i.e. IC reactor) and oxidation (i.e. Fenton's oxidation) processes for the removal of dye pollution. Decolorization and mineralization efficiency of treatments has been investigated in terms of color and COD removal. Thus, the aims of this study were to investigate the decolorization efficiency of textile wastewater using anaerobic inner loop reactor and Fenton process and to compare the efficiency of anaerobic process and Fenton process in treating real textile wastewater.

2. Materials and methods

2.1. Wastewater collection

Raw textile wastewater sample was taken from a textile finishing industry located in Rawalpindi (Koh-i-Noor textile Mills), Pakistan, where reactive dyes are being used to color cotton fabric. The samples were used after dilution to 25%, 50%, 75% and in full concentration (100%). The reactor was operated at HRT of 24 h at room temperature. Sampling cans were rinsed and cleaned with distilled water and then washed with sample during sample collection. Ambient pH, TDS, conductivity and DO and turbidity were measured using portable digital meters. The samples were delivered to the laboratory within a day of being taken and analyszed within 1 day. The samples were kept at 4 °C without any chemicals addition. Physico-chemical characteristics of wastewater are given in Table 1.

2.2. Experimental setup

The laboratorial-scale experiments were involved two types of treatment processes (a) biological treatment of the industrial wastewater using IC reactor, (b) chemical oxidation using Fenton's reagent with and without pH 3 adjustments of samples.

2.2.1. Startup of inner loop reactor

Raw textile industry wastewater was treated in a pilot scale IC reactor (diameter 12 cm, total height 160 cm, total tank capacity of 3.5 L). The reactor was provided with conical bottom of 20 cm length and a feed inlet pipe of 1.5 cm diameter avoid chocking during operation. An outlet weir was provided at the top (1.51 m), which is connected to an outlet gutter and outlet pipe to the effluent collection tank. The reactor had ports for sampling, feeding, effluent and gas collection. The peristaltic pump was used for pumping of influent into the reactor. The reactor was operated during summer when room temperature was around 35 ± 3 °C, so thermostat was not operated to save the energy.

The sludge used in the IC reactor was taken from anaerobic digester degrading industry wastewater. During the startup, the reactor was fed with tap water containing 400 mg/L dextrose as the carbon source. To gradually expose the microbial community with the inhibitory organic compounds an acclimation period was necessary, allowing the development of enzyme producing agents that are essential to induce biodegradation of dye intermediates. Measurement of COD reduction was used to assess stabilization of reactor. It has taken almost 30 days to have steady state COD reduction. Then the reactor was fed with effluent.

2.2.2. Fenton's oxidation

All the tests were performed in 250 mL glass beakers containing 100 mL sample. The calculated amount of ferrous sulfate powder and hydrogen peroxide (35% w/w) dose were added into the sample. The solution was stirred for 30 min using jar test apparatus. After 30 min of settling supernatant was collected, caustic soda was added to cease the reaction and been analyzed for color (λmax), COD, pH, temperature, DO, conductivity, turbidity, TS, TDS, TSS and heavy metals. PAM was not added in the reaction mixture so save the operational cost. The dose of Fenton's reagent for each dilution is given in Table 2.

2.3. Analytical procedures

The pH of the solutions and samples was monitored by using digital pH Meter (Jenway model 520). EC of the samples was determined by using conductivity meter (Jenway model 470) as µS. COD was analyzed using a colorimetric method after digestion of the samples in a COD digester (model TR320, Merck Spectroquant), according to standard method [2]. The spectrum was taken with UV–Vis Spectrophotometer (IRMeCO UV–Vis, U2020). Turbidity of the samples was measured by using Turbidimeter (Eutech, TN-100). Dissolved oxygen of the samples was determined by using DO meter (Jenway, 970).

Sample stirring for Fenton's oxidation was performed using Jar test apparatus. Heavy metals were measured by using Atomic absorption Spectroscopy (Perkin Elmer Model 920). Total solids were determined by following the standard method described [2].

Color was measured using UV/Vis spectrophotometer from 190 to 1100 nm wavelengths; the absorbance values of supernatants were measured. All the experiments were carried out in 4 mL quartz cuvette. COD removal efficiency of samples is calculated using formula (Eq. (1))

$$\frac{C_0 - C_t}{C_0} \times 100 \tag{1}$$

where C_0 is the initial concentration of COD of the textile wastewater, and C_t is the concentration of COD at the corresponding time (t).

Table 1
Characteristics of the sample wastewater used in this study.

Parameter	Unit	Concentration
pH	–	7.7 ± 0.115
DO	mg/L	0.3 ± 0
Temperature	°C	25.7 ± 0
Conductivity	µs	145 ± 1.01
Turbidity	NTU	188.6 ± 0.57
Total solids	mg/L	1731.6 ± 8
Total dissolved solids	mg/L	86.7 ± 0.28
Total suspended solids	mg/L	1697 ± 7
COD	mg/L	1132.6 ± 2.5

Table 2
Dose of Fenton's reagent for different dilutions.

Sample	Dose	
	pH 3	pH 7–8
25%	1:25*	1:25*
50%	1:25*	1:25*
75%	1:25*	1:25*
100%	1:25*	1:25*

* The ratios mean 1 part ferrous sulfate and 25 parts H_2O_2.