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Treatment Of Synthetic Dye Solution Containing Acid Red 131 Dye By Ozonation

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Abstract: Treatment of synthetic dye solution of Acid Red 131 dye was studied in a batch reactor using ozonation. Ozone was produced in a ozone generator by corona discharge. The amount of ozone consumed in the reaction was determined by measuring the ozone concentration at the inlet and outlet of the reactor using ozone analyzer. The effect of ozone dose, initial dye concentration and solution pH on the rate of decolorization was studied and the results were analyzed in terms of colour removal efficiency. The colour removal efficiency was found to increase with an increase in the ozone dose and decrease with an increase in initial dye concentration of the synthetic dye solution. The results with Acid Red 131 synthetic dye solution showed that maximum decolorization was obtained at the solution pH 11. A 100 % colour removal was obtained after 12 min of ozone treatment.
Keywords: Decolorization; Ozonation; Semi-batch reactor; Acid Red 131.

Introduction

In the last few decades, the environmental pollution has become one of the major problems across the world due to the rapid industrialization. Effluent from the industries contains toxic chemicals which require treatment prior to its discharge in to the aqueous eco system such as rivers, lakes, seas etc. Textile industry wastewater is considered as one of the major pollutant to the environment due to high discharge volume, organic/inorganic content and concentration of color. The textile wastewater generated in textile plants increase each year due to increase in the capacity and number of textile plants. The textile industry consumes large quantity of water and chemicals for various operations such as washing, drying, rinsing and finishing. The major pollutants in textile wastewater are suspended solids, total organic compound (TOC), colour and other soluble substances. Approximately 10-20% of the dyes used in the textile manufacturing does not adhere to the fibers during the dyeing process and are therefore present in the effluent generated from the dyeing industry. The wastewater mainly contains high level of the color from the dyes in the dyeing process, high level of TOC and COD due to used organics such as dyes, surfactants and heavy metals present in the dye structure. Moreover, some chemicals including salts, acids, bases and buffers used for the adjusting the pH also find their way in the effluent[1-5]. New environmental concerns and strict regulations are putting pressure on textile industries to reduce the pollutants and reuse the process water and the chemicals[6]. Conventional

wastewater treatment plants relying on biological and/or simple physico-chemical strategies are not adequate for complete decolorization and removal of dye residues because most of these compounds are highly resistant to biological and chemical processing[7-9]. Advanced oxidation is one of the most powerful methods for decolorization of textile waste water[10]. It is well known that ozone is a strong oxidant which is able to form a more powerful, non-selective hydroxyl radical at high pH values due to its high oxidation potential[11,12]. The main objective of this manuscript is to explore the potential of ozonation for the treatment of textile industry effluent, as a function of operating parameters for decolorization, e.g. ozone dosage, pH and dye concentration. In the present study, ozonation of Acid Red 131 dye solution was performed and the effect of operational parameters such as ozone dosage, pH of the solution and initial dye concentration in the solution was investigated. The Acid Red 131 dye was selected due to its high solubility in water, and its non-biodegradability[13].

Materials and methods

The schematic diagram of the experimental setup is shown in Figure 1. Air, drawn from the atmosphere was fed to an oxygen concentrator which operates on pressure swing absorption method to produce oxygen with more than 95 % purity. The pure oxygen was passed through a set of electrodes under high voltage potential in the ozone generator where oxygen gets converted into ozone using corona discharge. The oxygen flow rate to the ozone generator was kept constant at 5 LPM for all the experiments. The experiments were performed in a 20 liter reaction vessel (height 70 cm, diameter 20 cm) made of stainless steel-316. with batch mode of operation. The reaction vessel was filled with synthetic dye solution and ozone was injected in the reaction vessel by a venture injector installed on the recirculation loop. In the present study, commercial Acid Red 131 dye was used for all the experiments. The physical and chemical properties of the Acid Red 131 dye are presented in Table 1. The pH of the synthetic solution was measured using pH meter (EUTECH 510, India) and adjusted accordingly by adding H_2SO_4 and NaOH. Synthetic dye solution of Acid Red 131 dye was prepared using RO water to minimize interferences. The ozone oxygen mixture was introduced through venture injector as shown in fig 1. The ozone gas concentration was measured in the reactor inlet and outlet with an ozone analyzer (BMT 964 Germany). The ozone doze was defined as grams of ozone per meter cube of oxygen fed to the ozone generator. Samples were withdrawn from the bottom of the reaction vessel at regular time intervals and analyzed for decolorization. Decolorization of dye solution was measured with (UV- Vis Double Beam 3500, India) spectrophotometer.

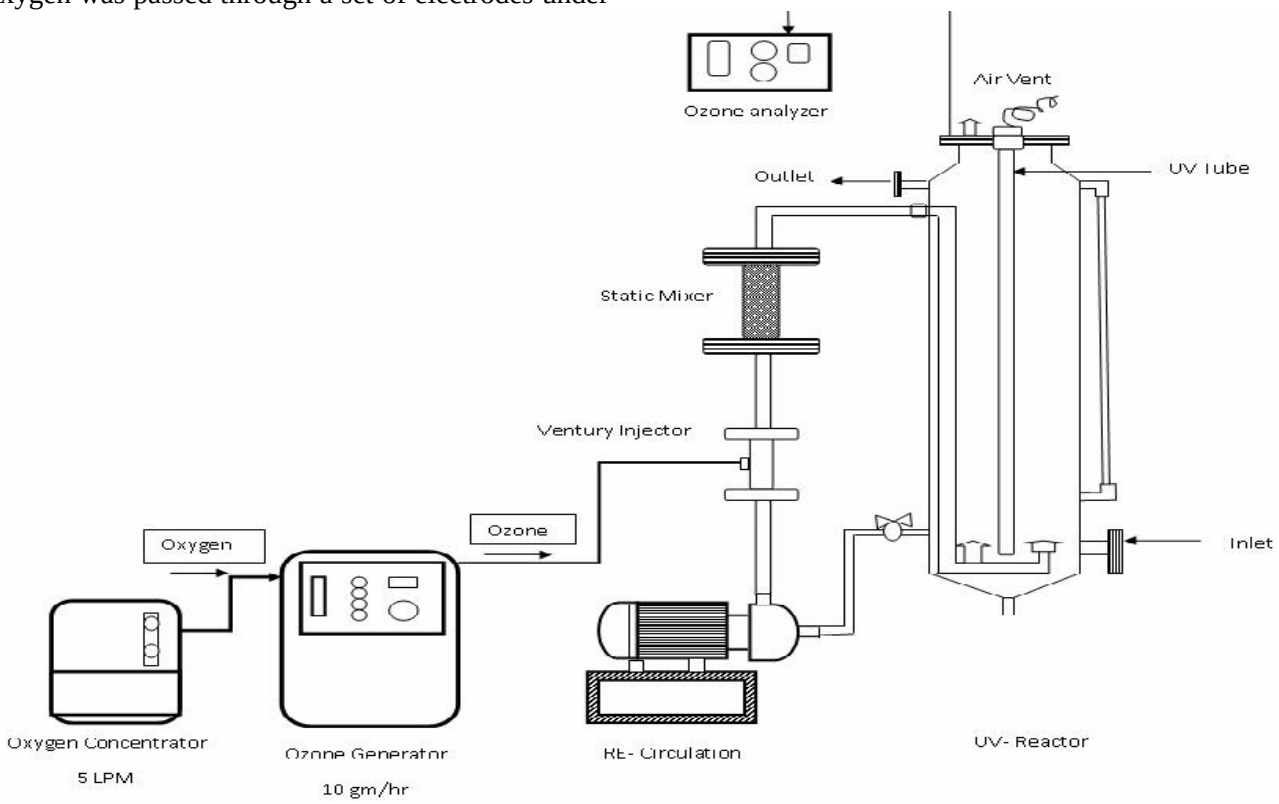

Figure 1 Schematic diagram of the batch reactor system

The colour removal efficiency was calculated using the following equation.

$$Colour\ Removal\ Efficiency = \frac{C_0 - C_i}{C_0} \times 100$$

where C_0 and C_i are the initial and final (after ozone treatment) dye concentrations in the synthetic solution.

Results and discussion

Effect of pH

The effect of pH of the solution on colour removal efficiency of Acid Red 131 by treatment with ozone is shown in Fig. 2.

It can be noticed from Fig.2 that an increase in pH from 3 to 7 did not result in significant change in the colour removal efficiency of Acid Red 131 dye. However, when the pH was increased to 11, the decolorization of the dye was faster compared to the other pHs and resulted in colour removal efficiency of 100% after 12 min of ozonation. The increased colour removal rate at pH 11 may be due to two effects (i) at high pH, the production of hydroxyl radicals leads to faster removal of dye, and (ii) at high pH, the H-N-R group of the dye molecule deprotonates, which makes the sites more reactive for the electrophilic attack by ozone[1].

Table 1 Characteristics of acid red 131 dye

Parameter	Value
Appearance	Powder
Color	Red
Odor	No
Dye Group	Anionic
Solubility in water	100 g/l
Acute Oral Toxicity	Above 5000mg/kg
Adverse effects	Inhalation of high vapor concentration may irritate eyes, nose and respiratory tract.
Λ_{max}	548 nm

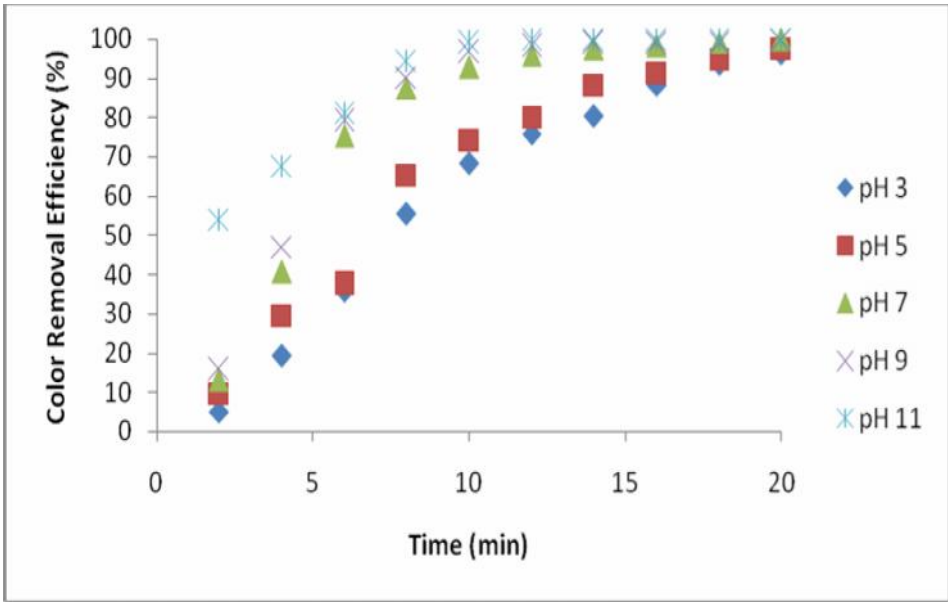

Figure 2 The effect of pH on decolorization of Acid Red 131 dye solution (initial dye concentration 50 mg/L, sample volume 10L, ozone dose 25g/m^3) at different time interval

Effect of inlet ozone dose

The experiments were carried out at different ozone dosages (12.7, 17.7, 25, 29.5 g/m^3) respectively and the results are shown in Fig.3.It can be noticed from Fig.3 that there was an increase in colour removal efficiency with an increase in the ozone dose at a particular time period. Further, the time required to achieve 100 % colour removal efficiency was found to decrease with an increase in ozone dose. The decolorization of Acid Red 131 dye solution was almost complete after 30, 28, 20 and 12 min of ozonation with inlet ozone dose of 12.7, 17.7, 25, 29.5 g/m^3 respectively this result is consistent with the theories of mass transfer[14]. According to these theories, as the ozone concentration increases in the air bubbles, the driving force for the transfer of ozone to the dye solution increases with a consequent increase in ozone concentration in the solution and rate of dye oxidation.

Effect of initial dye concentration

It has been reported in the literature that initial dye concentration plays a significant role on color removal efficiency[15,16]. The influence of dye concentration on colour removal efficiency was studied by performing experiments with different dye concentrations at a constant dose of ozone and the results are shown in Fig.4.It can be noticed from Fig. 4 that there was a decrease in colour removal efficiency with an increase in initial dye concentration. It can be further noticed that more time was needed to obtain maximum colour removal efficiency (greater than 96%) with an increase in initial dye concentration from (30 mg/L to 70 mg/L).

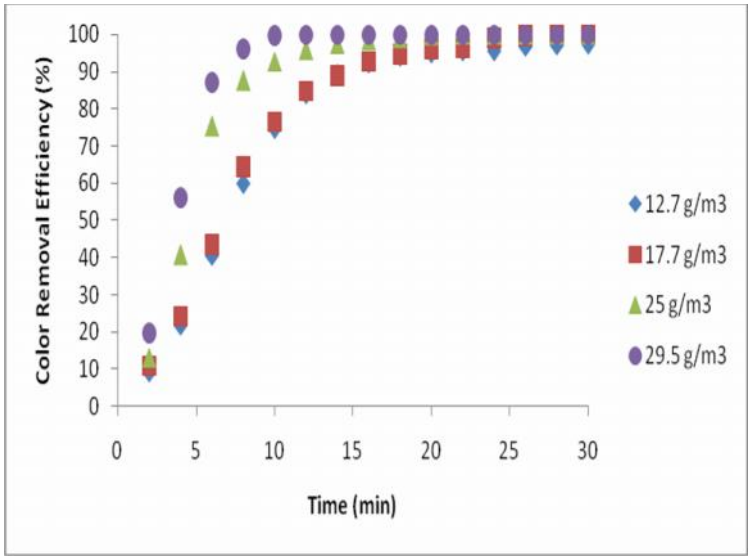

Figure 3. The effect of ozone dose on decolorization of Acid Red 131 dye solution (sample volume 10 L; pH = 7; initial dye concentration 50 mg/L) at different time intervals.

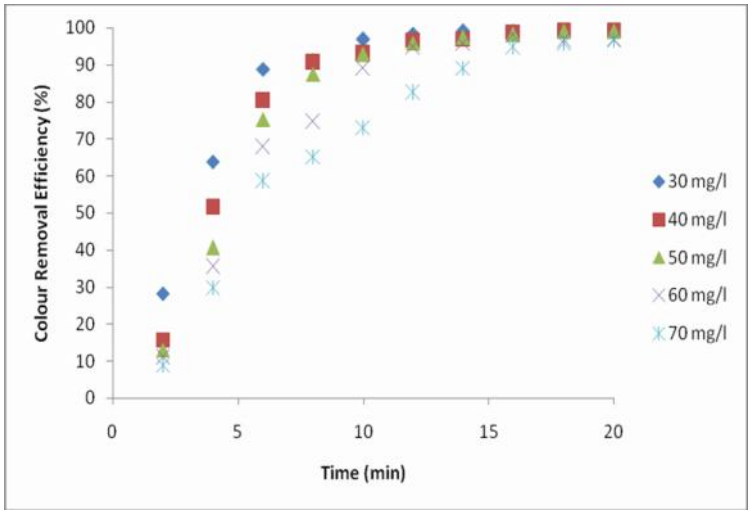

Figure 4. The effect of initial dye concentration on decolorization of Acid Red 131 dye solution (sample volume 10L, pH = 7, ozone dose 25g/m^3) at different time interval

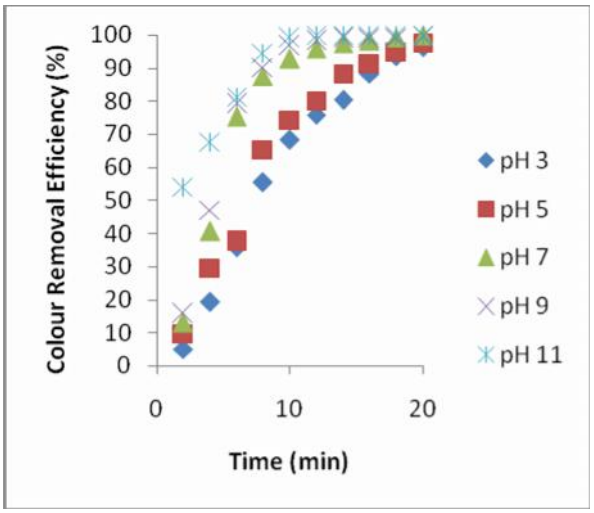

Figure 5a. The effect of pH on decolorization of Acid Red 131 dye solution by Ozonation, C_o=50 mg/L, Volume = 10 L, ozone dose 25g/m^3

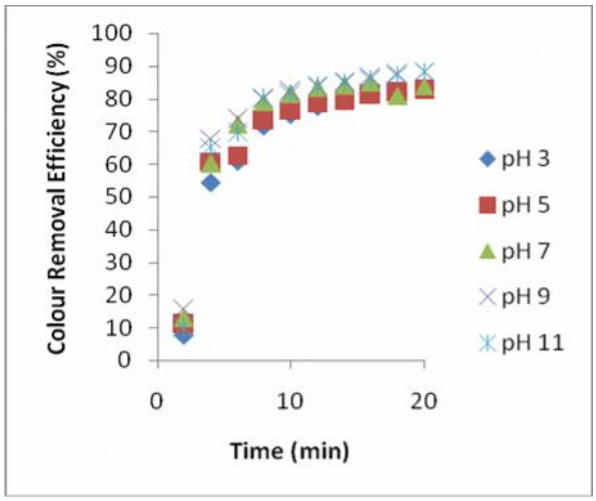

Figure 5b. The effect of pH on decolorization of Acid Red 131 dye solution by Ozonation/UV, C_o=50 mg/L, Volume = 10 L, UV emission 253.7 nm, ozone dose = 25g/m^3

Ozone / UV

The effect of pH of the solution on colour removal efficiency of Acid Red 131 by treatment with ozone / UV is studied and the results were compared with the ozonation as shown in Fig.5.It can be noticed from Fig.5b. that an increase in pH from 3 to 9 colour removal efficiency increased with increasing pH. This is may be due to two effects (i) at high pH, the production of hydroxyl radicals leads to faster removal of dye, and (ii) at high pH, the H-N-R group of the dye molecule deprotonates, which makes the sites more reactive for the electrophilic attack by ozone[1]. When further increases of pH up 9 to 11 the colour removal efficiency was decreased. This result may be because of dissociation of OH° in to oxygen anion radicals[17,18]. As shown in Fig.5a, 5b the colour removal efficiency was more in the case of ozonation as compared to the ozone/UV process.

Conclusions

The decolorization of Acid Red 131 dye by treatment with ozone was carried out in a batch reactor. The effect of ozone dose, initial concentration of dye and the pH of the solution on the colour removal efficiency were studied. Dye concentration, ozone concentration and pH of the solution were found to have a considerable effect on decolorization of the dye. The results showed that decolorization was maximum at the solution pH 11.Dye solutions with low dye concentrations and high ozone gas concentrations were found to decolorize faster. In case of effect of pH using ozonation and ozonation / UV the colour removal efficiency was more in the ozonation process.

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