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Photo-Oxidation Process – Application for Removal of Color from Textile Industry Effluent

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Abstract

A series of batch experiments were conducted to investigate the feasibility of hydrogen peroxide (H_2O_2), a strong oxidizing agent along with lathe turnings as a heterogeneous catalyst in presence of solar irradiation for the decolorization of textile industry effluent. Operating parameters such as pH, H_2O_2 concentration, and catalyst dosage affecting decolorization were investigated and optimal values were determined. A maximum decolorization of 86% was achieved. The results indicate advanced oxidation process (AOP) is one of the promising methods for textile industry effluent decolorization.

Keywords: Decolorization, effluent, lathe turnings, textile industry, solar irradiation.

Introduction

Textile industries use large amounts of water in their production processes and most of it is rejected as effluent. Textile industry effluent comprises of variety of dyes and chemical additives and posses a challenge for textile industry to treat this liquid waste of varying chemical composition, in an eco-friendly manner[1,2]. Conventional methods for color removal from textile industry effluents are: adsorption by activated carbon, electrochemical treatment, coagulation / flocculation, ozonation, reverse osmosis, membrane filtration, biological treatments and chemical oxidation process[3-8]. Membrane filtration, adsorption and coagulation / flocculation produce solid waste that requires additional treatment before disposal[9].

Advanced oxidation process (AOP) refers to chemical treatment process designed to remove organic materials in water and effluent by oxidation through reactions with hydroxyl radicals[10]. The objective of AOP is catalytic conversion of a strong oxidizing agent to hydroxyl free radicals which are more effective oxidizing agents in presence of UV or ultrasound. AOP with H_2O_2 as oxidizing agent has gained considerable interest due to its highly oxidative nature[11].

In the present study, decolorization experiments were conducted in a batch process using a strong oxidizing agent H_2O_2 with iron turnings waste from lathe operations in local machining industry (lathe turnings) as heterogeneous catalyst in presence of solar irradiation. The experimental data were analyzed and reported.

Material and Methods

Textile Industry effluent and its characterization: The effluent sample used for the present study was collected from the nearby textile industry and was preserved in the refrigerator at 4°C in accordance with the standard methods for the examination of water and effluent. The effluent was characterized in terms of pH, color, turbidity, chemical oxygen demand (COD), biological oxygen demand (BOD), and total dissolved solids (TDS) using standard methods[12]. The characteristics of the effluent are tabulated in table-1.

Table-1
Characteristics of Textile Industry effluent

S. No.	Characteristics	Value
1	COD (mg/l)	1540
2	BOD (mg/l)	770
3	pH	10.75
4	TDS (mg/l)	1990
5	Turbidity (NTU)	23

Experimental: A series of batch experiments were conducted to investigate the feasibility of oxidizing agent H_2O_2 along with lathe turnings as heterogeneous catalyst in presence of solar irradiation. Lathe turnings collected from nearby industry, cleaned to remove dirt, oil and then dried in an oven**.** All batch experiments were conducted on 500 ml of textile industry effluents for a time period of 30 minutes. Samples were collected at 5 minutes interval and oxidation was ceased by adjusting pH of the effluent to 7 using sodium hydroxide (NaOH). The collected samples were centrifuged for half an hour and were analyzed for color using UV-Vis Spectrophotometer according to Method 2120C in standard methods[12]. The effects of pH, oxidizing agent concentration, catalyst dosage on decolorization of textile industry effluent were further investigated by varying one variable at a time (OVAT) and the optimum values at which the maximum decolrization occurs were obtained.

Results and Discussion

Hydrogen peroxide effects on color removal: A batch experiment was carried out to investigate hydrogen peroxide effects on decolorization. Figure-1 shows the decolorization profile at pH value, 3 and H_2O_2 concentration, 20 ml/l. It can be seen that color removal was negligible (< 5%). Several studies have also stated negligible color removal when H_2O_2 alone was used for decolorization[13-16].

Effect of pH*:* A series of batch experiments were conducted to investigate the effect of pH on decolorization by maintaining H_2O_2 concentration and catalyst (lathe turnings) dosage as 20 ml/l and 2.5 g/l, respectively. pH values were varied in the range of 2 to 6. Figure-2 shows percentage decolorization vs. time at different pH values. It was observed that maximum decolorization of 86% was achieved at pH value, 3 and decolorization decreased with increase in pH. It can be attributed that in alkaline environment, H_2O_2 is unstable and easily decomposes to produce water and oxygen rather than forming hydroxyl radicals. At pH values < 4.0, ferrous ions decompose H_2O_2 catalytically yielding hydroxyl radicals most directly. However, at pH values higher than 4.0, ferrous ions easily form ferric ions, which have a tendency to produce ferric hydroxo complexes[17]. Variation of percentage decolorization with respect to pH is shown in figure-3. A polynomial relationship was established between percentage decolorization and pH for the given range of operating conditions, which is expressed as equation 1.

Effect of H_2O_2concentration: Effect of initial concentration of H_2O_2 on decolorization was carried out at optimum pH value, 3 and catalyst dosage, 2.5 g/l. H_2O_2 concentrations were varied in the range of 10 to 25 ml/l with an incremental of 5 ml/l. Figure-4 shows the effect of H_2O_2 initial concentration on decolorization. It was observed that decolorization increased with increase in H_2O_2 concentration and maximum decolorization (86%) was achieved at 20 ml/l. It was also observed that when H_2O_2 concentration was raised to 25 ml/l, decolorization decreased which is contributed to the increased concentrations of H_2O_2. The excess concentration of H_2O_2 will react with hydroxyl radicals that are already present in the solution to form water and oxygen and hence reduction in decolorization[15, 18]. Variation of percentage decolorization with respect to H_2O_2 concentration is shown in figure-5. It was observed that percentage decolorization varied as 2nd degree polynomial with respect to H_2O_2 concentration. Hence a polynomial relationship was established between percentage decolorization and H_2O_2 concentration for the given range of operating conditions, which is given as equation 2.

Effect of catalyst dosage: In order to investigate the effect of catalyst dosage (CD) on decolorization, experiments were conducted at optimum pH value and H_2O_2 concentrations of 3 and 20 ml/l, respectively. Catalyst dosage was varied in the range of 1 to 3 g/l with an incremental of 0.5 g/l. Figure-6 shows the variation of percentage decolorization at different time intervals. Maximum decolorization of 86% was achieved at catalyst dosage of 2.5 g/l. Variation of percentage decolorization with respect to catalyst dosage is shown in figure-7. It was observed from the experimental data that percentage decolorization varied as 3rd degree polynomial with respect to catalyst dosage and hence a polynomial relationship was established for the given range of operating conditions as equation 3.

$$\text{Decolorization}\ (\%) = 1.6633(pH)^3 - 23.041(pH)^2 + 89.797(pH) - 23.244 \quad (1)$$

$$\text{Decolorization}\ (\%) = -0.5162(\text{H}_2\text{O}_2)^2 + 19.832(\text{H}_2\text{O}_2) - 107.9 \quad (2)$$

$$\text{Decolorization}\ (\%) = -19.187(\text{CD})^3 + 110.21(\text{CD})^2 - 175.01(\text{CD}) + 129.25 \quad (3)$$

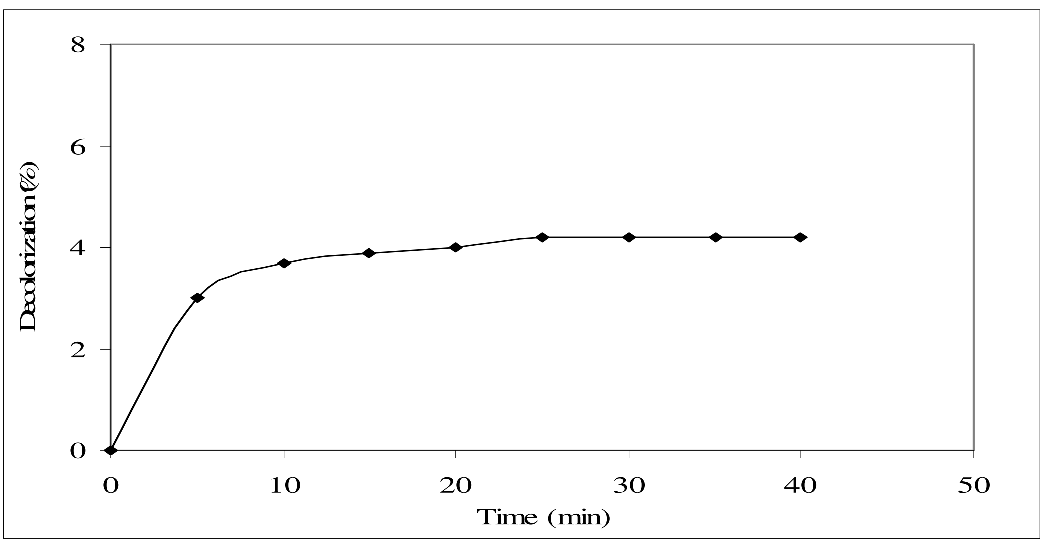

Figure-1
Effect of H_2O_2 alone on decolorization

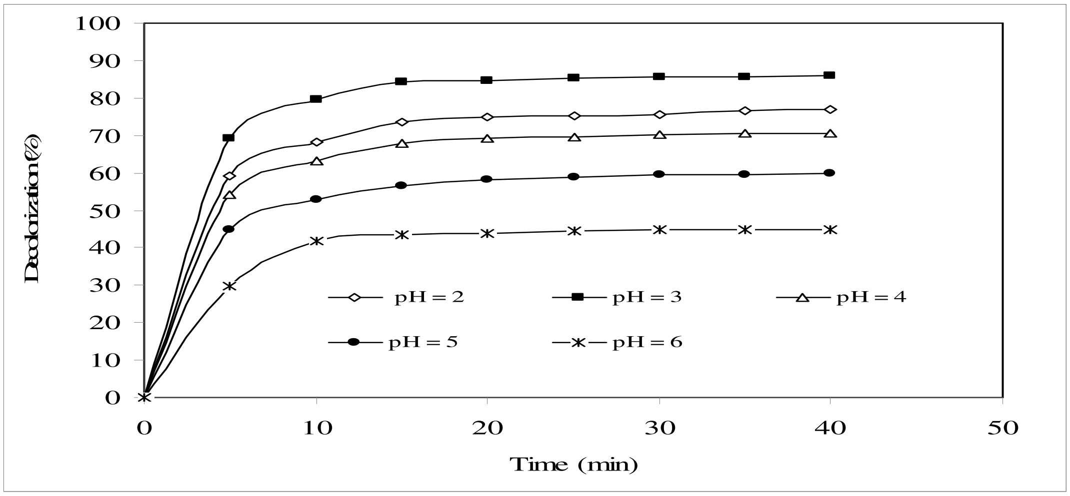

Figure-2
Effect of initial pH on decolorization (H_2O_2 concentration = 20 ml/l, Catalyst dosage = 2.5 g/l)

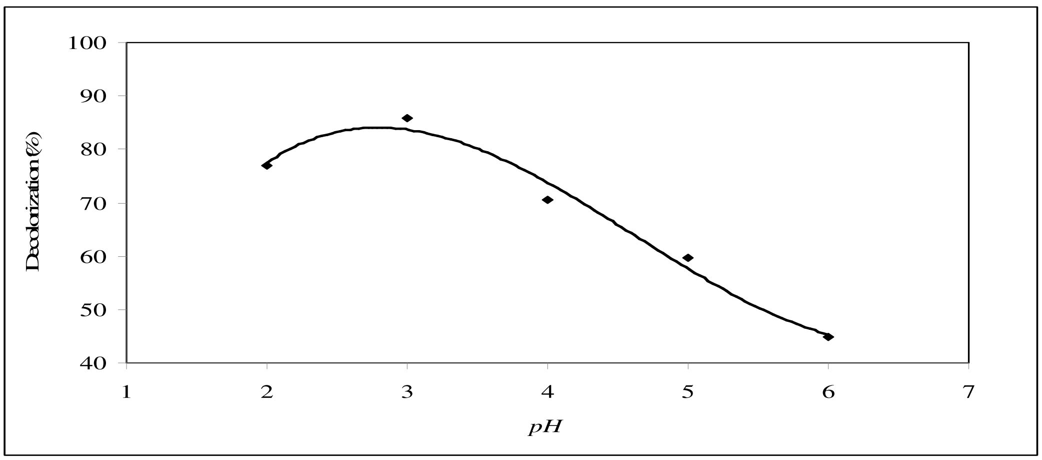

Figure-3
Decolorization vs. pH

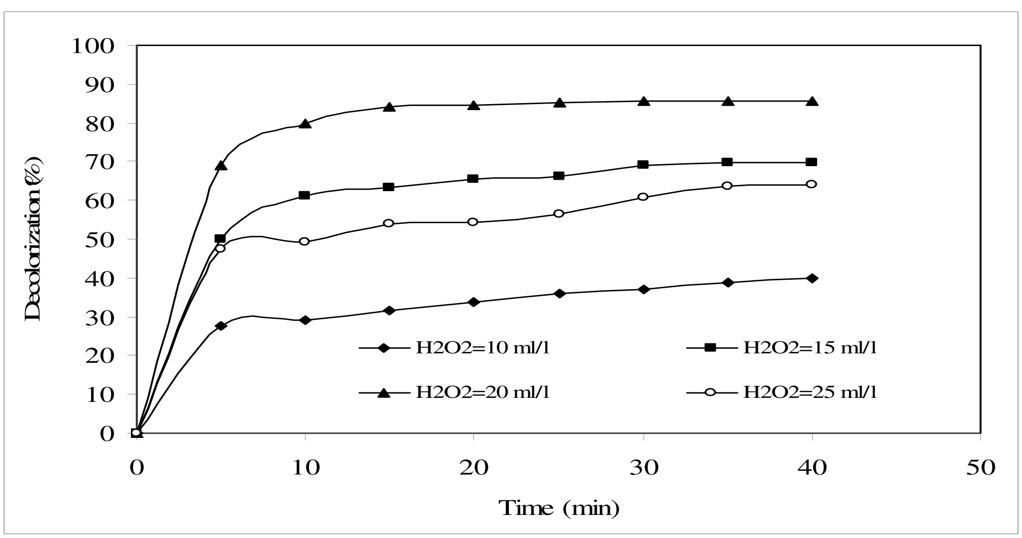

Figure-4
Effect of initial H_2O_2 concentration on decolorization (pH = 3, Catalyst dosage = 2.5 g/l)

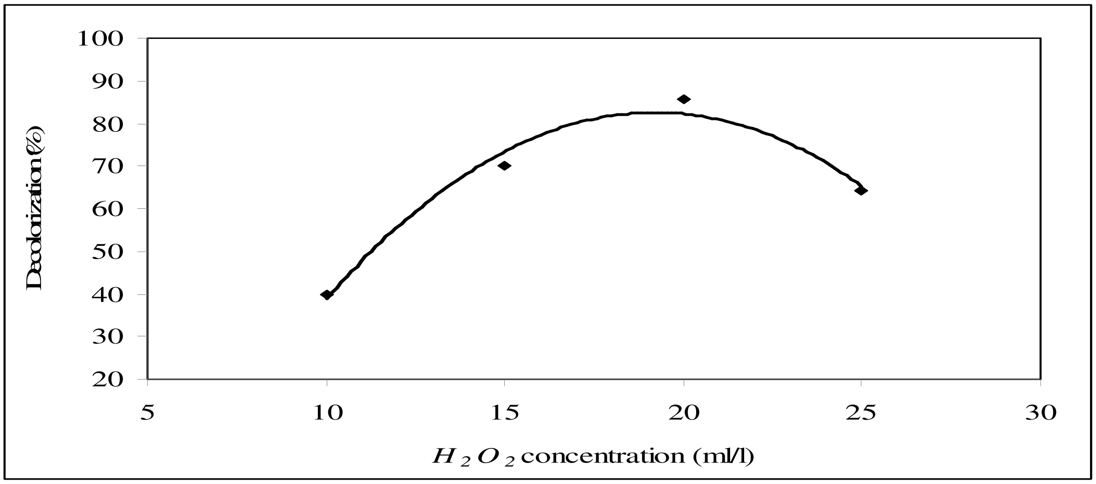

Figure-5
Decolorization vs. H_2O_2 concentration

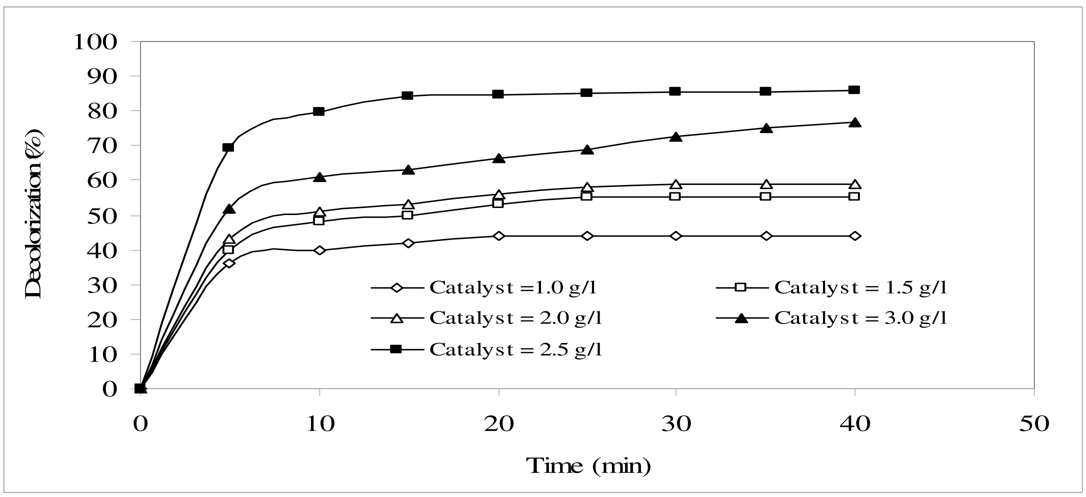

Figure-6
Effect of catalyst dosage on decolorization (pH = 3, H_2O_2 concentration = 20 ml/l)

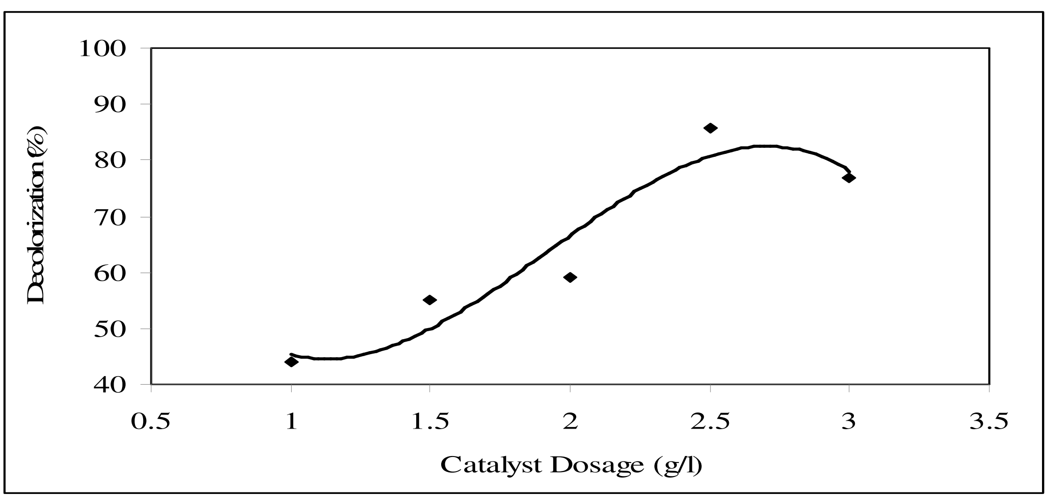

Figure-7
Decolorization vs. catalyst dosage

Conclusion

Feasibility of hydrogen peroxide along with lathe turnings in presence of solar irradiation for decolorization of textile industry effluent was investigated by a series of batch experiments. The optimal operating parameters were determined and maximum decolorization of 86% was achieved at pH value, 3, H_2O_2 concentration, 20 ml/l and catalyst dosage, 2.5 g/l. This process was found to be very efficient and economical for textile industry effluent decolorization as it uses lathe turnings an industrial waste as catalyst. The ease in process operation and reuse of catalyst make AOP a promising treatment method for textile waste decolorization.

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