Decolorization of reactive dyes wastewater using Fe(III)/H₂O₂

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Abstract – The treatment of dying industry wastewater is a difficult problem owing to the complex composition and difficulty for biodegradable. Decolorization of the Reactive Dye Benefix Red 5B in wastewater was investigated in laboratory-scale batch experiments using Fe(III)/H₂O₂. The dye degradations were studied for the result of dye removal efficiency and reduction in chemical oxygen demand (COD). The effect of operating parameters, such as pH, time, chemical concentration (H₂O₂ and Fe³⁺), and dye concentration have been determined. The result showed that the efficiency of color and COD removal is strongly depend on the initial concentration of Fe(III) and H₂O₂. The reaction has been proved to be highly effective for the removal of Reactive Dye Benefix Red 5B in aqueous at pH 6.75 and dye concentration of 200 ppm at Fe(III)/H₂O₂ mole ratio of 1 and initial [Fe(III), H₂O₂]/ dye mole ratio of 0.03. A color removal efficiency of 95% and COD reduction of more than 70% from wastewater were already achieved after 24 hour. The results will be useful in designing for the dye contaminated wastewater treatment plants for decolorization of effluents from textile dyeing and finishing process containing reactive dyes.

Keyword: Decolorization, Dye degradation, Wastewater, Reactive dyes, Textile dyes
1. Introduction

Synthetic textile dyes and other industrial dyestuffs constitute a major class of chemicals in textile industries. Significant losses of dyes occur during the manufacturing and processing and these lost chemicals are discharged in the wastewater effluent. These effluents have adverse effect on the environment if not treated properly. Among the overall production of dyes, Reactive dye are very toxic to the surrounding environment if released without treated. Benefix Red 5B is a reactive dye that widely used in textile industry, ink and paint.

The effluent containing reactive dye is red in color, toxic, and has high chemical oxygen demand (COD). The reactive dye causes considerable damage to the aquatic life as does not allow sunlight to pass through and thereby affects the photosynthesis of aquatic plants. The treatments are required to reduce the color and chemical oxygen demand (COD).

The Fe(III) ion and the hydrogen peroxide act as catalyst to decompose dye molecule. The hydroxyl radicals are produced and regenerated in their original state at the end of the cyclic reactions according to the following reaction.

\[
\begin{align*}
\text{Fe}^{3+} + \text{H}_2\text{O}_2 & \leftrightarrow \text{FeOOH}^{2+} + \text{H}^+ \\
\text{FeOOH}^{2+} & \rightarrow \text{Fe}^{2+} + \text{HO}_2^- \\
\text{Fe}^{2+} + \text{HO}_2^- & \rightarrow \text{Fe}^{3+} + \text{HO}_2 \\
\text{Fe}^{3+} + \text{HO}_2^- & \rightarrow \text{Fe}^{2+} + \text{O}_2 + \text{H}^+ \\
\text{H}_2\text{O}_2 + \text{HO}_2^- & \rightarrow \text{H}_2\text{O} + \text{HO}_2 \\
\end{align*}
\]

Hydroxyl radicals from reaction of Fe(III) ion and the hydrogen peroxide

\[
\begin{align*}
\text{RH} + \text{HO}_2^- & \rightarrow \text{H}_2\text{O} + \text{R}^* \\
\text{R}^* + \text{H}_2\text{O}_2 & \rightarrow \text{ROH} + \text{HO}_2^- \\
\text{R}^* + \text{O}_2 & \rightarrow \text{ROO}^* \\
\text{ROO}^* + \text{RH} & \rightarrow \text{ROOH} + \text{R}^* \\
\end{align*}
\]

These reaction schemes are very attractive because Fe$^{3+}$ ions and hydrogen peroxide is relatively cheap and environmentally safe.

The aim of the work was to treat of dying wastewater contaminated with Benefix Red 5B in laboratory-scale batch experiments using Fe(III)/H$_2$O$_2$. The dye degradations were studied concentration of Fe(III) and H$_2$O$_2$, pH, time for the result of dye removal efficiency and reduction in chemical oxygen demand (COD).

2. Materials and Methods

2.1 Material

Reactive dye Benefix Red 5B was obtained from textile industry. Reactive dye solution was prepared 200 ppm. Other reagents namely, H$_2$O$_2$ 1 M and Fe(NO$_3$)$_3$ 0.00414 M Both the reagents were used in a 1:1 ratio (v/v) for the experiments.

2.2 Experimental

Experimental equipment for decolorization of reactive dye wastewater including magnetic stirrer, beaker 500 ml, pH-meter, uv-vis spectrophotometer, Fe(NO$_3$)$_3$, H$_2$O$_2$ and dye from textile industry. Assimilate equipment is shown Fig.1.

2.3 Decolorization analysis

The change of dye concentration was determined quantitatively by the UV-vis photometer using the calibration curve of standard dye solution. After decolorization, the sample solutions were taken from the Experimental every 1 hour after add already Fe$^{3+}$ and H$_2$O$_2$ until getting the clear solution. The samples were measuring an absorbance at 400-700 nm using UV-vis spectrophotometer. The concentrations of dye solution before and after each experiment were determined quantitatively. The calibration curve (straight line, $R^2 = 0.9910$) of the dye solution was constructed from standard solution of synthetic dye solution at various concentrations. The efficiency was defined as Equation (1).

\[
\% \text{ Decolorization Eff.} = \frac{C_0 - C_1}{C_0} \times 100 \quad (1)
\]

Where $C_0$ (mg/L) and $C_1$ (mg/L) is original concentration of dye solution and the concentration of dye solution at time t, respectively.

3. Results and discussion

3.1 Effect of H$_2$O$_2$ and Fe(III) concentration

In order to observe the effect of H$_2$O$_2$ and Fe(III) concentration on the rate of Reactive dye degradation, experiments were carried out by varying the dose of H$_2$O$_2$ and Fe(III) is appropriated. H$_2$O$_2$ 1 M and Fe(NO$_3$)$_3$ 0.00414 M, ratio of [Fe$^{3+}$, H$_2$O$_2$/dye water is 0.03.
3.2. Effect of pH on decolorization

In order to optimize the pH, experiments were carried out under acidic, COD removals were plotted against the pH neutral and alkaline condition at 3.70, 5.17, 6.74 and 7.45 respectively as explained the result in Fig. 3.

To investigate the effect of initial pH, solutions of Reactive Dye Benefix Red 5B were irradiated at various initial pH (3.70, 5.17, 6.74 and 7.45). The results (Fig. 4) showed differences in the degree of decolorization of the dye at different pH values.

3.3. Effect of time for decolorization

Efficiency of decolorization depend on time that long time efficiency of decolorization is increase from the first period.
3.3. Effect of Fe(III)

After decolorization this experiment used Fe(III) that remain in dyewater so test dose of Fe(III) in dyewater after decolorization by Atomic absorption spectroscopy

![Graph](image)

Fig.7 Effect of Fe(III) concentration of Fe(III) is low than standard pH = 6.74 is lowest

4. Conclusions

Decolorization of Reactive Dye Benefix Red 5B in wastewater is greatly enhanced using Fe(III)/H$_2$O$_2$. Degradation of the dye is effectively at pH 6.74. The Reactive Dye Benefix Red 5B degradation is depend upon the initial Fe(III) and H$_2$O$_2$ concentration and Fe(III)/H$_2$O$_2$ ratio. This technology can be applied for colored wastewater treatment.

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References