

Effect of reaction parameters for degradation of dye using fenton oxidation process

Amit Kumar Behera
Assistant Professor,
Department of Chemical Engineering,
VSSUT Burla.

ABSTRACT

Decolorization of textile brilliant Green (BG) dye has been studied using Fenton ($\text{H}_2\text{O}_2/\text{Fe}^{+2}$) reagent. The influence of reaction parameters such as solution Fe^{2+} and H_2O_2 doses have been treated on color removal efficiency. Color reduction efficiency with Fe^{3+} and Fe^{2+} was observed as 73 and 68.%, respectively. Fenton process was highly efficient for color removal from synthetic BG dye effluent. Dye removal of 98.7% is achieved within 30 min in the Fenton treatment.

Keywords: Fenton oxidation, Brilliant green.

1. INTRODUCTION

1.1 Introduction

Dyes are used as coloring agents in many industries, such as textile, plastic, cosmetic, food and paper [1, 2]. They generate colored effluents containing various types of dyes and pigments. These effluents are normally discharged to natural water bodies without treatment. Such effluents are characterized by fluctuating pH with large load of suspended solids and high oxygen demand [7]. Textile and pulp-paper industries discharge highly colored effluents, which retain the color even after the conventional biological treatment process. Tertiary treatment measures [8–10] are employed to remove color by adsorption on activated carbon.

Environmental pollution is one of the major threats to human and ecosystem. Natural water system contamination is one of the major problems as large amount of water is used in our daily life. Wastewater containing dye is one of the primary sources of water pollution. Cationic dyes are more toxic as compared to anionic dyes [2]. Resistive properties and toxic nature of these dyes cause series of environmental and aesthetic pollution. In addition to these, repeated inhalation of dye components cause many disorders, such as damage of nervous system, liver and thyroid problems. Physical contacts with dyes also irritate eyes and skin [3]. Reduced light penetration in aquatic system due to presence of textile dyes severely affects photosynthesis process in aquatic plants, which is also a major aspect of water pollution. Effluents of textile and dye industries laden with a suspended solids (SS), high chemical oxygen demand (COD) and other soluble substances [16]. Most components effluents, except color, can be reduced by chemical, physical or biological

treatments. Therefore, removal of residual color of treated effluent is also a major parameter to be studied and investigated.

1.1.1 Fenton's reagent

Fenton's reagent is a mixture of hydrogen peroxide and Fe(II) catalyst used to oxidize organic contaminants of wastewater. Fenton's reagent could degrade toxic organic compounds into harmless products. It was developed in the 1890 by Henry John Horstman Fenton as an analytical reagent.

2. MATERIALS AND METHODS

2.1 Brilliant green dye

Brilliant green, 4-(diethylamino) cyclohexa-2,5-dien-1-yliden] diethyl ammonium hydrogen sulfate, is chosen as model dyeing agent for the present study. It was procured from Merck, India. The molecular structure of drug is shown in Figure 2.1. BG dye is cationic in nature and represented with molecular formula, $C_{27}H_{33}N_2.HO_4S$, with molecular weight of 482.64 g/mol. It is supplied as green colored powder and has melting point of 210°C. It is highly water soluble up to 100 g/L at 20 °C.

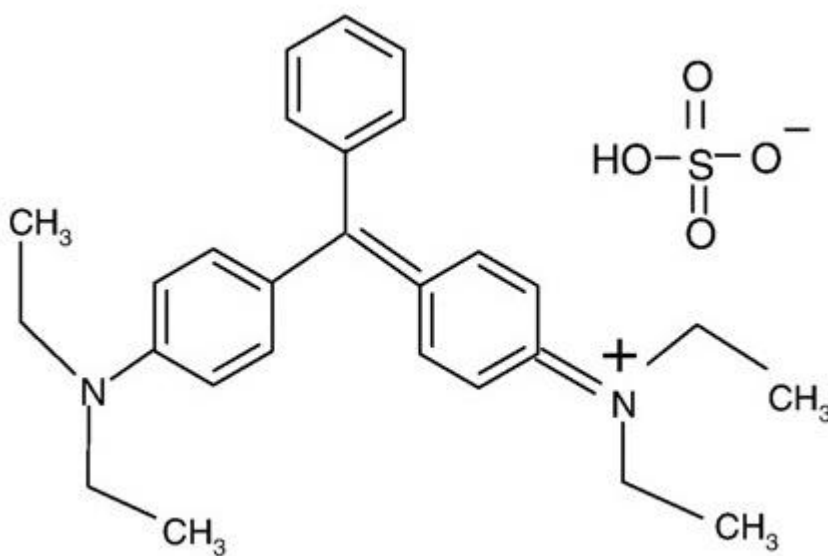


Figure 2.1: Chemical structure of Brilliant Green (BG).

2.2 Regents and chemicals

All reagents and chemicals were of AR grade and procured from Merck India. Deionized water was used for dilution and solution preparation.

2.2.1 Fenton's reagent

Ferrous ammonium sulfate (FAS), $(\text{NH}_4)_2\text{SO}_4\text{FeSO}_4\cdot 6\text{H}_2\text{O}$, and 50% hydrogen peroxide (H_2O_2) was used for preparation of Fenton reagents. Stock solution of 0.1M Fe^{+2} was prepared by dissolving $(\text{NH}_4)_2\text{SO}_4\text{FeSO}_4\cdot 6\text{H}_2\text{O}$ in deionized water. FeCl_3 was used to prepare 0.1M Fe^{+3} stock solutions.

Phosphate buffer: Equal volume of 0.2 M dibasic sodium phosphate (Na_2HPO_4) and 0.2 M monobasic sodium phosphate (NaH_2PO_4) was mixed to get buffer solution of pH 6.8. This buffer was used to raise the solution pH to stop the Fenton reaction.

2.3 Experimental procedure

A cylindrical borosilicate beaker (1L) was used as batch reactor, with 400 mL of synthetic effluent of BG dye. BG dye of 50 mg L^{-1} was prepared and Fe^{2+} was added as catalyst. The pH of solution was adjusted in range of 1 to 3 with appropriate volume of $0.1\text{ N H}_2\text{SO}_4$. Fenton reaction was initiated with addition of hydrogen peroxide. The solution was agitated at 270 rpm using a magnetic stirrer (Make and model). All reaction experiments were carried at room temperature ($\sim 30^\circ\text{C}$). Fenton reaction in the sample was stopped by raising the solution pH to ~ 7 with appropriate volume of phosphate buffer (~ 6.8) or 0.1N NaOH . Suspended iron flocks were then separated by centrifugation at 1600 rpm for 20 min. The supernatant obtained was analyzed for dye, Fe^{+2} , H_2O_2 concentrations.

3. RESULTS AND DISCUSSION

The Fenton reaction parameters such as initial drug concentration, amount of oxidants, catalysts and nature of wastewater significantly affecting BG dye removal. The detailed investigations of these parameters are explained in following section.

3.1 BG dye removal in presence of Fe^{+2} and Fe^{+3} (no H_2O_2 addition)

Only Fe(II) and Fe(III) salt were employed find out their removal effect on BG dye at pH 3.0. Both the species of iron are known to precipitate at $\text{pH} > 6.0$ and with the increase in solution pH, Fe(II) is reduced to Fe(III). So, all experiments of BG dye removal were conducted at pH 3.0 to minimize both the effects. The role of iron species on dye is illustrated in Figure 3.3. Fe^{3+} is more efficient in BG dye removal as compared to Fe^{2+} and resulting in 73.51 % and 68.39 % dye removal efficiency. In case of Fe^{2+} , dye removal rate was fast at $< 1\text{ min}$ and within 5 min it attained the steady condition. While Fe^{3+} had slower removal rate at $< 1\text{ min}$ as compared to Fe^{2+} , but removal efficiency was high towards the completion of the reaction.

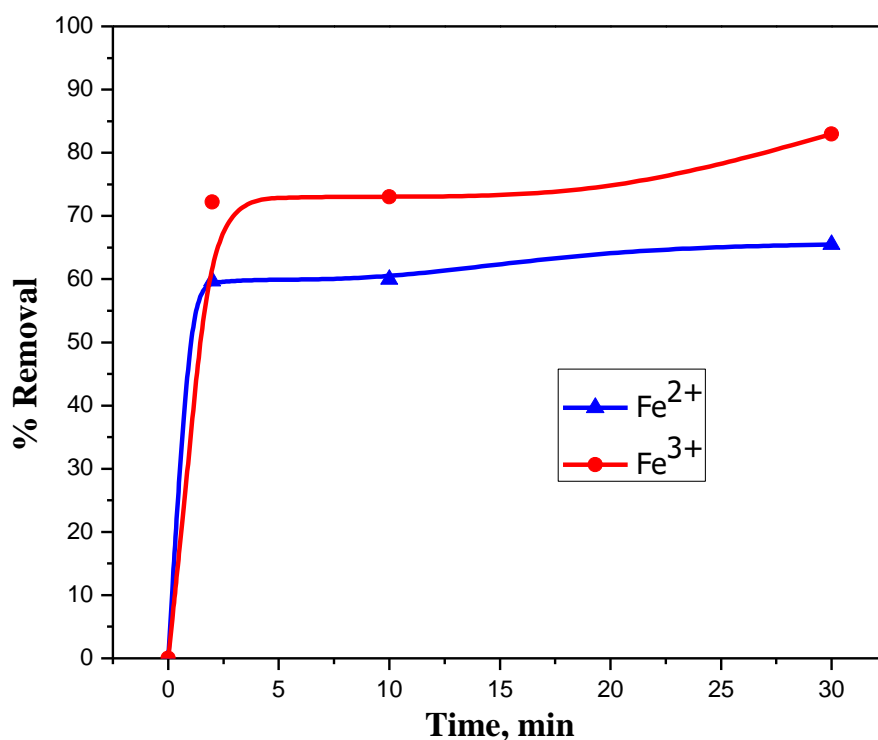


Figure 3.1: Effect of BG decolorization in presence of Fe(II), Fe(III) without H₂O₂.

3.2 Fenton oxidation process (FOP) for BG dye removal

Fenton oxidation with 50 mg L⁻¹ BG dye was conducted with Fe²⁺ (1mM) and hydrogen peroxide (10mM) at pH 3.0. BG dye removal efficiency with time is shown in Figure 3.4. Dye removal rate was initially fast (<1 min) and it decreased with time. Maximum removal as 98.7% was achieved within 30 min. Decrease in dye removal rate with time is due to less availability of BG dye in the reaction solution.

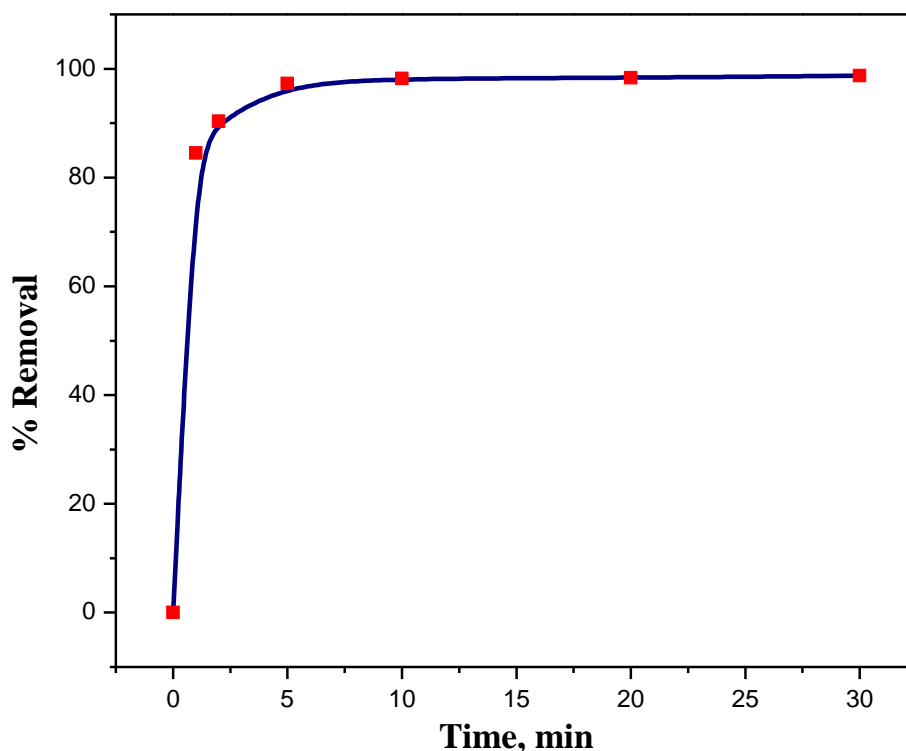


Figure 3.2: Effect of BG decolorization in presence of Fenton reagent.

Synthetic BG dye effluent has COD of 60 mg L^{-1} and after Fenton reaction the supernatant COD level was reduced to 4 mg L^{-1} . Fenton oxidation is able to remove about 93.3% of initial COD. Central pollution Control Board (CPCB) India, set the standard discharge limits of 250 mg L^{-1} COD in the treated effluent. Present studies report the significance of Fenton reaction in COD removal.

4. CONCLUSION

The present study considered the removal of BG dye at definite solution. Following are the major conclusion obtained from the experiments conducted:

- Fe^{3+} is more effective in BG dye removal as compared to Fe^{2+} .
- Fenton oxidation is more efficient in BG dye removal then only Fe(II) and Fe(III) addition. Maximum dye removal was achieved was 68.39, 73.51 and 98.7 % with Fe(II), Fe(III) and FOP respectively.

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