J. Mater. Environ. Sci. 5 (5) (2014) 1406-1411
ISSN : 2028-2508
CODEN: JMESCN

Degradation of zenative yellow BF3R dye by the fenton process

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Received 28 Jan. 2014; Revised 12 May 2014; Accepted 15 May 2014

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Abstract

The aim of this work was to study the degradation of the zenative yellow BF3R dye in aqueous solution using Fenton process. The degradation rate was strongly dependent on the reaction time and the initial concentrations of Fe^{2+}, H_2O_2, and the dye. The effects of these parameters have been studied and optimum operational conditions of these processes were found. Maximum decolorization (90%) efficiencies were achieved for 0,1 mM of H_2O_2, 0,01 mM of Fe^{2+} and 10 mg/l of dye concentration after 3h of reaction time. The experimental results showed that the Fenton's reagent was effective for the degradation of zenative yellow BF3R dye with a low concentration of H_2O_2 and Fe^{2+}.

Keywords: Degradation, Zenative yellow BF3R, Fenton process, Oxidation, Optimization.

Introduction

Worldwide generation of wastewater effluents from a lot of industries such as textile, cosmetic, printing, drug and food processing contain color compounds which cause serious environmental problems. It was reported that approximately 10–15% of overall production has been released into the environment causing different toxic, mutagenic or carcinogenic problems [1]. Actually, the removal of dyes from wastewater is a challenge to the related industries, because the synthetic dyes used are stable compounds and difficult to destroy by common treatments [2]. The reactive dyes are most important class of synthetic organic dyes used in the textile industries and are therefore common industrial pollutants. These dyes are found to be non-biodegradable. Various physical/chemical processes (coagulation, flocculation, adsorption on activated carbon, reverse osmosis) and biological processes have been used for wastewater treatment. Biological processes are not effective enough to decolorize dyes of high photo stability while physical/chemical processes are not strong enough to decompose the dye. Hence sludge generation and adsorbent regeneration are the principal weak-nesses of these processes [3].

Recently, advanced oxidation processes (AOP) have received considerable attention because it is possible to degrade organic compounds and color from wastewaters [4]. Among these AOPS, Fenton's reagent is particularly interesting due to its low price, low toxicity of its reagents (Fe (II) and H_2O_2), and the simplicity of its technology. Several studies already conducted have shown that the reaction of Fenton's reagent is effective in the degradation of organic compounds [5]. Fenton’s reagent is a combination of H_2O_2 and Fe^{2+}. In this process, H_2O_2 decomposes catalytically by means of Fe^{2+} at acid pH, giving rise to hydroxyl radicals [6]:

$$Fe^{2+} + H_2O_2 \longrightarrow Fe^{3+} + HO^{\cdot} + OH^{-} \qquad (1)$$

The main objective of this work is to determine the influences of various parameters on the degradation of zenative yellow BF3R by the Fenton process in aqueous solution. The effect of concentration of H_2O_2, Fe^{2+}, the dye and the reaction time were investigated to determine the optimal operating conditions for a better performance of the degradation.

2. Materials and methods

Solutions of zenative yellow BF3R dye ($C_{20}H_{20}N_4O_{12}S_{3}.{}_{2}K$) of different concentrations were prepared in distilled water. These solutions were then homogenized by stirring until a complete dissolve of the dye. The pH of the reaction mixture was adjusted by adding sulfuric acid and was measured by a pH-meter. In a study, the highest yield was obtained at pH 3.0 by the Fenton's oxidation process [7- 9].

The dye oxidation was achieved by Fenton's reagent which was composed of a mixture of $FeSO_4.7H_2O$ and H_2O_2 33%. The necessary quantities of Fe^{2+} and H_2O_2 were added simultaneously in the dye solution. The experimental device was constituted of a perfectly agitated reactor in which a volume (500 ml) of solution was studied. Fenton treatment of zenative yellow BF3R was carried out at 25 °C at atmospheric pressure. The temperature affects the reaction between H_2O_2 and Fe^{2+} [4, 10] .High working temperature has also some disadvantage that both of the investment and operational costs would be high to increase the wastewater's temperature [11].The maximum absorbance wavelength of zenative yellow BF3R was found to be 408 nm. The kinetics of the oxidation was followed by taking samples at regular time intervals. These samples are filtered before determining the residual concentration of the dye by UV / Visible spectroscopy (JASCO V-630 Spectrophotometer). The chemical structure of zenative yellow BF3R is shown in Fig 1.

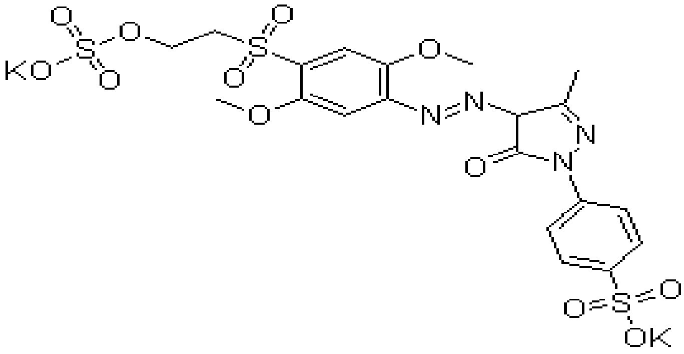

Figure 1: Structure of Zenative yellow BF3R dye.

3. Results and discussion

3.1. Effect of Fe^{2+} dosage

The $HO^{\cdot}$ radicals are trapped by Fe^{2+} ions in excess as shown in reaction (2) [12-14]. To appreciate the effect of Fe^{2+} on the yield of zenative yellow BF3R discoloration by the Fenton process and to determine the most appropriate concentration of Fe^{2+}, a series of experiments were conducted for different concentrations of [Fe^{2+}] changing from 0.005 to 0.15 mM (Figure2).

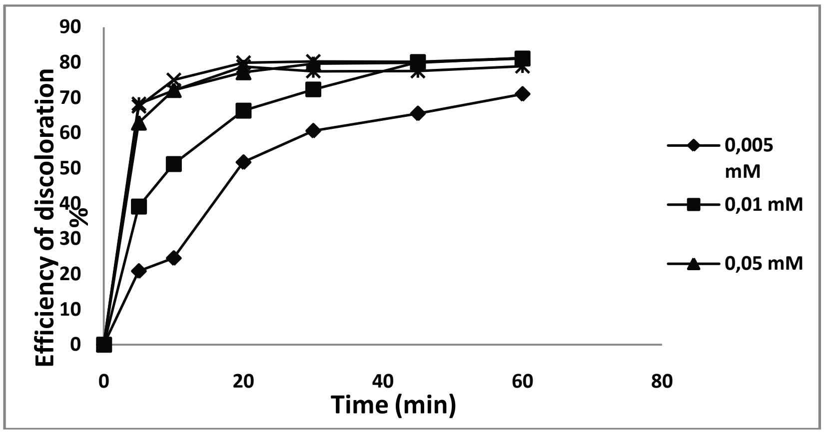

Figure 2a: Kinetics of discoloration according to different concentrations of $FeSO_4$.
C_0=10 mg/l; [H_2O_2]= 0.1mM, pH=3.

As shown in Figure 2a, the initial rate of zenative yellow BF3R discoloration varies with increasing Fe^{2+} concentration. Until 10 min, the yield is affected by relatively low concentrations of Fe^{2+} and reaches its maximum at around 0.10 mM. Therefore, after about 60 min of reaction time a maximum of degraded compound 81% was observed for 0.01 mM, and also for a concentrations of 0,05 and 0,1 mM with formation of a complex (brown color) that can be the ferric hydroxide Fe $(OH)_3$ (reaction 2). (Figure 2b)

$$Fe^{2+} + HO^{\cdot} \rightarrow Fe^{3+} + HO^{-} \qquad (2)$$

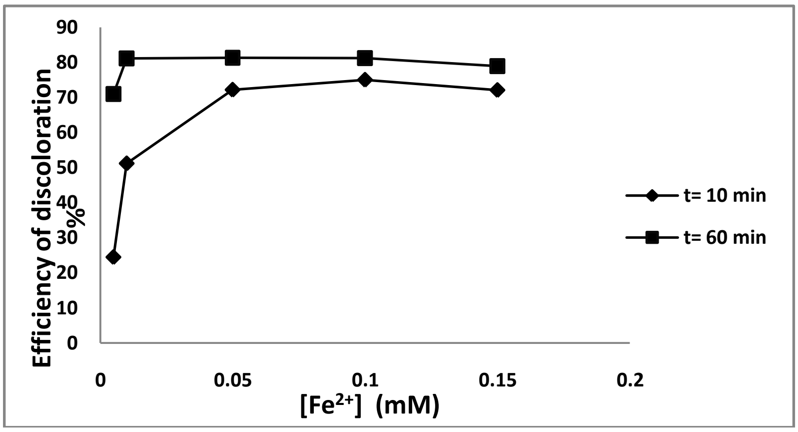

Figure 2b: Effect of $FeSO_4$ concentration on the zenative yellow BF3R discoloration efficiency.
C_0=10 mg/l; $[H_2O_2]$= 0.1 mM; pH=3.

3.2. Effect of H_2O_2 concentration

During the Fenton process, hydrogen peroxide plays a very important role as a source of hydroxyl radical generation. To determine the concentration of H_2O_2 giving the maximum zenative yellow BF3R discoloration efficiency, the series of tests were conducted at constant dye concentration (10 mg/l) and Fe^{2+} concentration (0.01 mM) while the H_2O_2 concentration was varied from 0.01 mM to 0,2 mM. (Figure 3a). The discoloration efficiency according to time for different concentrations of H_2O_2 shows that the dye degradation yield increases with increasing concentration of H_2O_2. When the initial concentration in H_2O_2 increases to 0.1 mM, the yield reached 81.1% after 60 min of contact time. Beyond this concentration, discoloration yield decreases (Figure 3b). Because the degradation of dye starts with the attack of the hydroxyl radicals that are generated from the H_2O_2 reaction with Fe^{2+} ion, more H_2O_2 molecules added to the system will generate more $^{\cdot}OH$ radicals and thus increase the dye degradation rate. However, too high H_2O_2 concentration will consume the $^{\cdot}OH$ radicals and thus decreases the dye degradation rate [15-17].

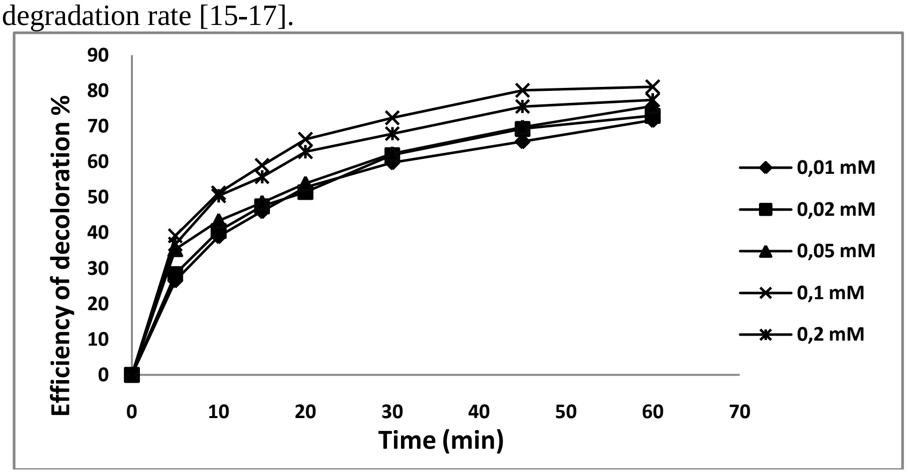

Figure 3a: Kinetics of zenative yellow BF3R discoloration in presence of different concentrations of H_2O_2.
C_0=10 mg/l; $[FeSO_4]$ = 0.01 mM; pH=3.

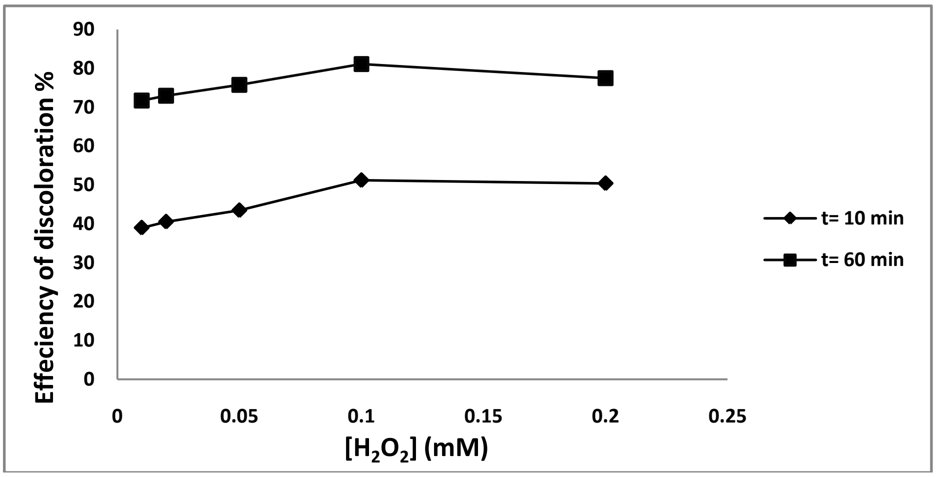

Figure 3b: Effect of H_2O_2 concentration on the zenative yellow BF3R discoloration efficiency.
C_0=10 mg/l; [$FeSO_4$] = 0.01 mM; pH=3.

3.3. Effect of initial concentration of dyes

The series of experiments were conducted at constant Fe^{2+} concentration (0.01 mM) and H_2O_2 concentration (0,1 mM) while the dye concentration was varied from 5 mg/l to 20 mg/l. The influence of the concentration of dye on the performance of discoloration is shown in Figure 4a.From this figure, we can note that when the initial dye concentration increases the yield of discoloration decreases. We also note that the increase in initial dye concentration leads to a reduction in the initial rate and the yield of discoloration (Figure 4b). This is due to non-availability of sufficient number of hydroxyl radicals. The presumed reason is that when the initial concentration of zenative yellow BF3R is increased, the $^{\cdot}OH$ concentration is not increased correspondingly. However, the higher the concentration, the more the dye decolorized in 20 min. This happens because the increase in concentration enhances the interaction between the dye and $^{\cdot}OH$ [18].

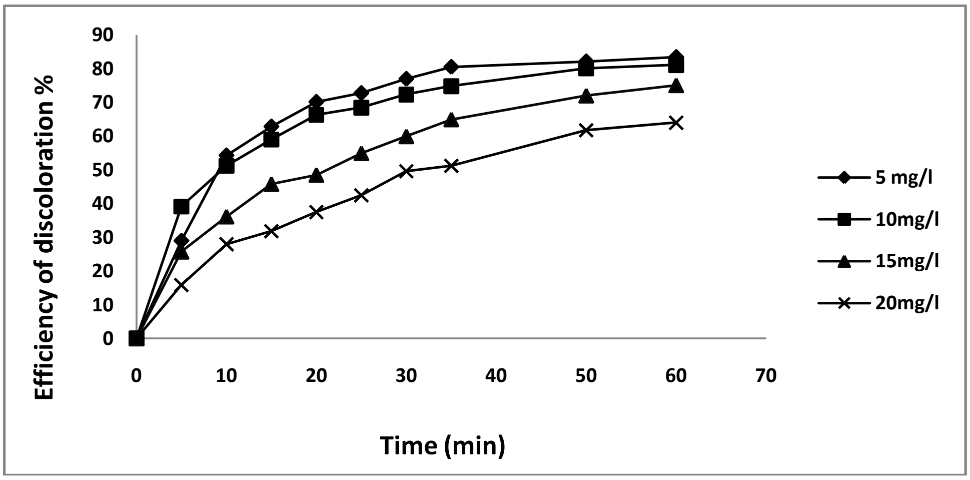

Figure 4a: Kinetics of zenative yellow BF3R discoloration at different initial concentrations.
[$FeSO_4$]=0.01 mM; [H_2O_2]=0.1 mM; pH=3.

3.4. Effect of reaction time

Reaction time is a key parameter in Fenton process, because not only treatment performance but also reactor volume is associated with it [19]. Figure 5 showed the effect of reaction time on the yield of zenative yellow BF3R discoloration during the Fenton process. In general, the zenative yellow BF3R discoloration efficiency increased with the reaction time prolonged.

The yield of discoloration increased rapidly at the beginning of Fenton reaction. The discoloration efficiency in the first 1 h period was 84.11%. Then it increased slightly and arrived at 89% corresponding to the reaction time of 3 h.

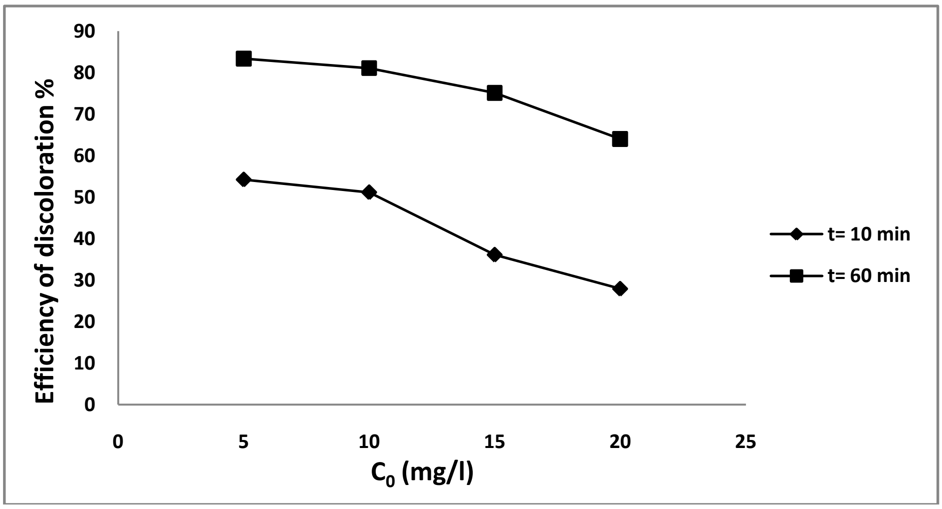

Figure 4b: Effect of the initial concentration of dye on the discoloration efficiency.
$[FeSO_4]$=0.01 mM; $[H_2O_2]$=0.1mM; pH=3.

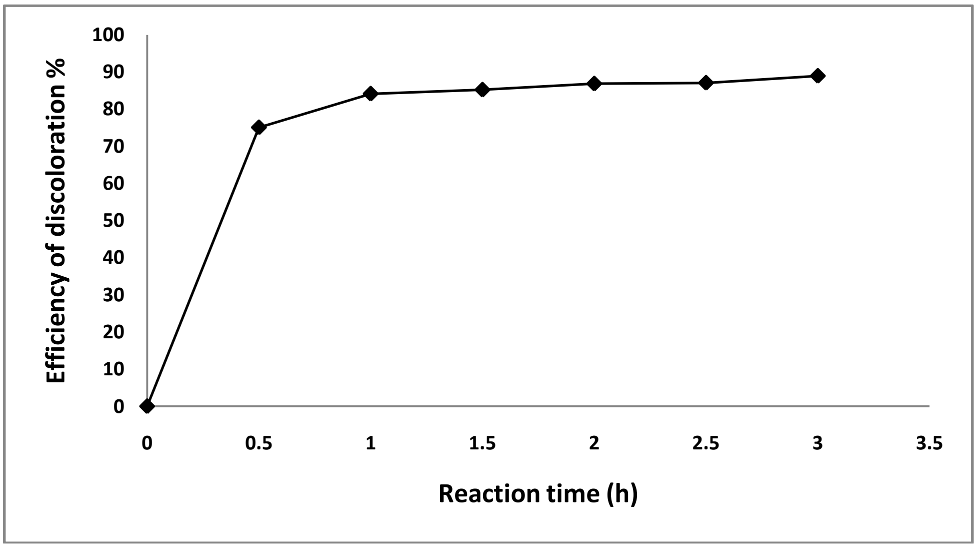

Figure 5: Effect of reaction time on discoloration efficiency. C_0=10 mg/l; $[Fe^{2+}]$= 0,01 mM; $[H_2O_2]$= 0,1 mM; pH=3.

3.5. Spectral changes of zenative yellow BF3R during decolorization process

The changes in the absorption spectra of zenative yellow BF3R solution during the decolorization process at different reaction times are shown in Figure 6. As can be seen from the spectra, before the treatment, the UV–vis spectrum of zenative yellow BF3R was characterized by one main band in the visible region, with its maximum absorption at 408 nm.

It was clearly observed that the absorption peak at 408 nm disappeared almost completely (90%) to 3h of reaction. This indicated a considerable and almost complete decolorization of 10mg/l zenative yellow BF3R can be achieved in 3h in the presence of 0,1 mM H_2O_2 and 0,01 mM of catalyst.

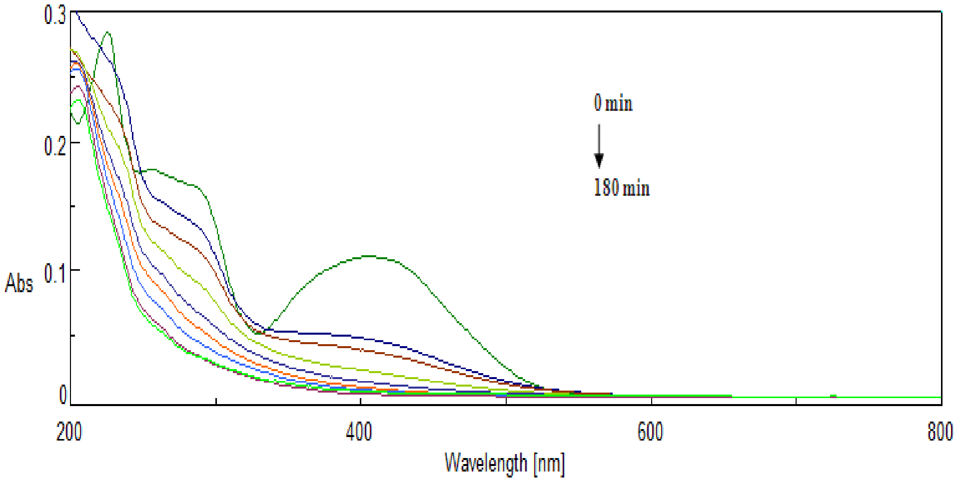

Figure 6: Variations of UV–vis absorption spectra for zenative yellow BF3R. C_0=10 mg/l; [Fe2^+]=0,01 mM; [H_2O_2]= 0,1 mM; pH=3.

Conclusion

1. Decolorization of zenative yellow BF3R dye in aqueous solution by Fenton oxidation process has been studied on different experimental conditions, including initial concentrations of Fe^{2+}, H_2O_2, the dye and reaction time.
2. The optimum conditions were observed at Fe^{2+} concentration of 0,01 mM and H_2O_2 concentration 0.1 mM with dye concentration of 10 mg/l.
3. The results showed that a Fenton process is powerful method for decolorization of dye.

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(2014); http://www.jmaterenvironsci.com