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FULL LENGTH ARTICLE

Degradation of methyl orange using Fenton catalytic reaction

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Abstract Oxidation by Fenton reactions a proven and economically feasible process for destruction of a variety of hazardous pollutants in wastewater. We report herein the oxidation of methyl orange using a Fenton reaction at normal laboratory temperature and at atmospheric pressure. The effects of different parameters like the dosages of H_2O_2 and Fe^{2+}, initial concentration of dye and pH of the solution, on the oxidation of the dye present in dilute aqueous solutions are found. The results indicate that the dye can be most effectively oxidized in aqueous solution at dye: Fe^{2+}:H_2O_2 molar ratio of 1:3.5:54.2. It was found that more than 97.8% removal of the dye could be achieved in 15 min in the pH 2.79 at room temperature. The results will be useful for designing the treatment systems of the various dyes containing wastewater.

1. Introduction

Dye pollutants from the dyestuff manufacturing, dyeing, printing and textile industries are important sources of environmental contamination. The effluents discharged from these industries are usually strongly colored, and the direct release of the wastewater into receiving water body will cause damage to both aquatic life and human beings due to their toxic, carcinogenic and mutagenic effects [1,2]. Azo dyes, characterized by the presence of one or more azo groups (N═N) bound to aromatic rings, are the largest and most important class of synthetic organic dyes. It has been estimated that more than 50% of all dyes in common used are azo dyes because of their chemical stability and versatility [3].

A variety of physical, chemical, and biological methods are presently available for treatment of wastewater discharged from various industries. Biological treatment is a proven technology and cost-effective, but it suffers from a number of disadvantages. Physical methods such as liquid–liquid extraction, ion-exchange, adsorption, air or steam stripping, etc. are also ineffective on pollutants which are not readily adsorbable or volatile, and have further disadvantage that they simply transfer the pollutants to another phase rather than destroying them. In contrast, chemical oxidation methods can result in almost complete mineralization of organic pollutants and are effective for a wider range of organics. The oxidation with

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Fenton reaction based on ferrous ion and hydrogen peroxide is an effective technology for destruction of a large number of hazardous and organic pollutants [4].

Fenton reaction is a homogeneous catalytic oxidation process using a mixture of hydrogen peroxide (H_2O_2) and ferrous ions (Fe^{2+}) in an acidic medium, which was firstly discovered by Fenton in the 1890s [5]. In the last decades, Fenton's reaction has been introduced into wastewater treatment processes, and it has been shown that a variety of refractory organics could be effectively degraded through Fenton reaction without producing any toxic substances in water environment [6,7]. The mechanism that describes Fenton reaction mainly includes the following reactions [6,8]:

$$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + HO^{\cdot} + HO^- \quad (1)$$

$$Fe^{3+} + H_2O_2 \rightarrow Fe^{2+} + HOO^{\cdot} + H^+ \quad (2)$$

$$Fe^{3+} + HOO^{\cdot} \rightarrow Fe^{2+} + H^+ + O_2 \quad (3)$$

$$HO^{\cdot} + H_2O_2 \rightarrow HOO^{\cdot} + H_2O \quad (4)$$

$$HO^{\cdot} + Fe^{2+} \rightarrow Fe^{3+} + HO^- \quad (5)$$

$$HO^{\cdot} + HO^{\cdot} \rightarrow H_2O_2 \quad (6)$$

$$HO^{\cdot} + HOO^{\cdot} \rightarrow O_2 + H_2O \quad (7)$$

There are several studies related to using of Fenton reaction for the treatment of azo dyes wastewaters [9–12].

The previous researches have shown that a number of azo dyes could be effectively degraded by Fenton reaction. And the degradation efficiency of dyes was mainly dependent on their chemical characteristics, the generation rate and concentration of $HO^{\cdot}$ in the process.

2. Materials and methods

2.1. Reagent

Methyl orange ($C_{14}H_{14}N_3NaO_3S$) provided from Aldrich Chemical Company; ferrous sulfate ($FeSO_4 \cdot 7H_2O$) provided from LOBA Chemic; Hydrogen peroxide (30% v/v); and hydrochloric acid provided from BIO CHEM.

All the chemicals were of analytical grade and were used without further purification. A known dye concentration was prepared in distilled water and used as the stock solution for all studies. The properties of MO are shown in Table 1.

2.2. Experimental procedures

All experiments were carried out at room temperature and pH of the solution was adjusted by using hydrochloric acid or sodium hydroxide using a pH meter.

The required amount of Fe^{2+} and H_2O_2 was added to the dye solution. The Fenton reaction was started by the addition of H_2O_2. Immediately after the addition of H_2O_2 the concentrations of the dye were determined spectrophotometrically at 464 nm, at different times in order to study the degradation of the methyl orange.

2.3. Analytical methods

The UV–Vis spectra of the MO were recorded from 200 to 800 nm by using Thermo Scientific Evolution 300 UV–Vis Spectrophotometer. The spectrum showed that the maximum absorbance wavelength (λ_{max}) of MO was at 464 nm. Therefore the absorbance of MO in the experiment can be determined at 464 nm. Before the measurement, a calibration curve was obtained using the standard MO solution with a series of known concentrations.

The dye degradation efficiency was used in the study:

$$\text{Degradation efficiency } \% = \left(1 - \frac{C_{dye,t}}{C_{dye,0}}\right) \times 100$$

where $C_{dye,t}$ and $C_{dye,0}$ are the concentration of dye at λ_{max} reaction time t and 0, respectively.

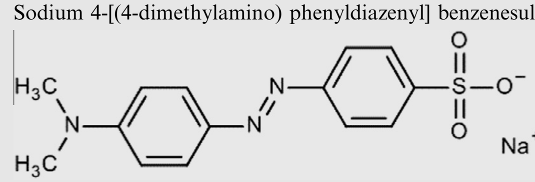
3. Results and discussion

3.1. Optimization of system parameters

3.1.1. Effect of H_2O_2 dosage on the degradation of methyl orange

H_2O_2 plays a very important role as a source of $HO^{\cdot}$ generation in Fenton's reaction. The effect of H_2O_2 dosage on the

Table 1 Properties of methyl orange.

Properties of methyl orange	
IUPAC name	Sodium 4-[(4-dimethylamino) phenyldiazenyl] benzenesulfonate 
Molecular formula	$C_{14}H_{14}N_3NaO_3S$
Molar mass	327.33 g/mole
Density	1.28 g/cm^3, solid
Melting point	> 300 °C
Boiling point	Decomposes
Solubility in water	Soluble in water

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