Study effect of titanium dioxide on the photocatalytic degradation of methyl violet dye

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Abstract

The organic pollutant methyl violet dye photocatalytic degradation has been investigated using the UV irradiation and TiO₂ as a catalyst. The degradation process included the study of the initial dye concentration, light intensity, catalyst weight, the effect of intensity of light, and effect of temperature to approach the best conditions for the optimum photo-degradation efficiency of dye. The optimum photocatalytic degradation of methyl violet dye was at 0.15 g/100cm³ of dosage mass of TiO₂ and 10 ppm of the dye. Photocatalytic degradation of methyl violet dye was at 9 mW/cm² light intensity. The percentage efficiency of degradation methyl violet dye equals 97.46%.

Introduction

Hundreds of commercial and synthetic dyes have been used in different fields of industry as colorants [1-3]. Where these dyes are considered as water pollutants and one of those is methyl violet (Fig.1)[3-5]. Methyl violet can be used to dye cotton, leather and papers[6]. While, in the biological fields it is used as a stain for bacterial identification [7].

Chemical structures of Methyl violet

To minimize the effect of these dyes on the environment different strategies have been used. Such strategies include the photocatalytic degradation, adsorption and using biological removals [8-11]. One of these effective methods is the first one (photocatalytic degradation) with the use of many synthetic and commercial catalysis. One of these commercial catalysts is TiO₂ which has been widely used despite its disadvantages including the wide band gap, the photocatalytic process under the UV radiation and the fast combination of electrons and holes[12], however, it has been used because of its low cost, low reactivity, photo-stability and safety[13]. In this
work TiO$_2$ was used to degrade methyl violet using UV irradiation with studying the effect of various parameters such as initial dye concentration, light intensity and the catalysis dosages on the dye degradation.

**Materials and Methods**

1. **Chemicals**
   a. Titanium dioxide (TiO$_2$): purity (99%), particle size (100) mesh, supplied by Fluka AG.
   b. Methyl violet dye supplied by sigma – Aldrich.

2. **Photo reactor and Procedure**

Experiments were carried out in glass photochemical reactor. The cylindrical annular – type reactor consisted of two parts. The first part was an outside thimble. Running water was passed through the thimble to cool the reaction solution. Owing to the continuous cooling, the temperature of the reaction solution was maintained of room temperature. The second part was an inside thimble and the reaction solution (volume 100 ml) was put in the reaction chamber. Schematic diagram of photo-chemical reaction as shown in figure (1):

![Fig.1: Main parts of the photocatalytic cell used in Photocatalytic degradation of methyl violet dye](image)

**Result and Discussion**

1. **The Effect of titanium dioxide mass on photo catalytic degradation of methyl violet dye**

   The loading mass of titanium dioxide for methyl violet dye degradation was studied using 10 ppm concentration of this dye with 10ml/min of air and at room temperature. Fig.2 shows the photocatalytic degradation of the dye using different loaded masses of titanium dioxide. The degradation of methyl violet was gradually increased as the mass of titanium dioxide has been increased until it reached 0.15g /100ml, then it gradually decreased. When the catalysts mass is 0.15g /100ml it provided the highest light absorption. The less efficiency of the dye photo-degradation at higher masses of the catalysts (more than 0.15 g /100ml) was because of the limited light absorption which will be only on the first layers of the dye and the other layers of its solution do not receive enough light [14]. Moreover, the scattering of light with...
high catalysts loading, this resulted in low photon intensity, so the strong absorption of titanium dioxide below the optimum value 0.15 g /100 ml.

Fig. 2: The effect masses of titanium dioxide on Photo-catalytic degradation of methyl violet dye.

2-The Effect of initial methyl violet dye concentration on photo catalytic degradation processes

This effect has been studied using different concentrations of the dye (10–70) ppm, 0.15 g / 100 ml of the catalysts, ( 9 ) mW/cm² light intensity and at RT. It’s obvious that the dye degradation decreased when its concentration increased as shown in Fig. 4. It was found that the best dye concentration was 10 ppm that could cover high amount of TiO₂. In this stage high concentration of the activated catalysts resulted from the absorption of maximum exciting photons. Furthermore, at higher concentrations of methyl violet the light penetration will be hindered and that led to no excited state of the dye [15,18].

Fig.3: Photo degradation efficiency of methyl violet dye

3-Effect of inorganic anions on photo catalytic degradation processes

Sodium chloride was used as a source of chloride ions (inorganic anions). The effect of these anions on the photocatalytic degradation of the studied dye using TiO₂ was investigated. The degradation rate of methyl violet was 91.61% in the absence of chloride, while it was 54.19% in the presence of them (10 ml) (Fig.5 and 6). A further decrease in this rate to 42.7% when the amount of chloride ions increased; This
inhibition of photocatalytic activity is due to the chloride ions behaves as scavengers of ·OH radicals[19-21]:

\[
\text{Cl}^- + h^+ \rightarrow \text{Cl}^* \quad (1)
\]

\[
\cdot \text{OH} + \text{Cl}^- \rightarrow \text{Cl}^* + \text{OH}^- \quad (2)
\]

**Fig. 4:** Photo-catalytic inhibition in the presence of inorganic anions

**Fig. 5:** Photo degradation efficiency of methyl violet dye

**Conclusion**

The photocatalytic degradation of methyl violet increased with increasing the amount of TiO$_2$ catalyst dosage and the optimum value was equal 0.15 g / 100 ml of the catalyst. In addition the photo-degradation process of dye increased with decreasing dye concentration because of the decrease in the OH$^-$ concentration that adsorbed on the catalyst surface and the optimum value of dye was 10 ppm. In addition, the photocatalytic degradation of the studied dye followed the first order reaction. Moreover, the photocatalytic degradation process of the methyl violet decreased with the increase of the inorganic anions and the photo-degradation efficiency change from 91.61% in absence of these anions to 54.19% in the presence of them.
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