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Photocatalytic removal of eosin dye from aqueous solution over titanium dioxide

Hazim Y Al-Gubury*, Suad T Saad, Nour Abd Alrazzak and Ruqaia M Naif

Department of Chemistry, College of Science for Women, University of Babylon, Hilla, Iraq

suad_saad80@yahoo.com

Abstract. A Various concentrations of Eosin dye were irradiated using titanium dioxide as a catalyst. The irradiation was carried out using the catalyst (0.1gm/100ml), mercury lamp 125 Watts from external source and at Rt. The effect of TiO₂ on the photocatalytic degradation of Eosin was studied in various conditions such as, studying the effect of loaded mass of titanium dioxide, effect of eosin dye concentration and effect of inorganic anions.

1. Introduction

Environment including water, air and soil is subjected to threat by different kinds of pollutants where these pollutants affect the human life [1-2]. Water pollution is one of the serious problems which has received more attention [3]. Many reasons are contributed to this problem and one of them is dyes [4]. Dyes have received more attention due to their toxicity, strong color and stability [5,6]. However, they have been used in industry for coloring for example, in textiles industry and as a result of this use the discharged water is contaminated with these dyes [7-8].

Different techniques have been used to treat this problem and one of them is using the photocatalytic degradation [4,9]. This type of degradation can be achieved using various metal oxides (semiconductors) as catalysts and one of them is titanium dioxide [10,11]. TiO₂ has been extensively used in photocatalytic degradation because it's efficient, cheap, photocatalytic active, and non- toxic [12-14].

In addition, the work of this kind of degradation relies on the oxidation process which leads to the formation of the reactive free radicals [15-17]. These radicals include hydroxyl and superoxide which resulted from the irradiation of the catalyst in the presence of water and oxygen and as a result this leads to the oxidization and degradation of these dyes [18].

In this paper TiO₂ was used as a catalyst to degrade Eosin 'Figure 1'. Different parameters have been measured to study the degradation efficiency of Eosin.

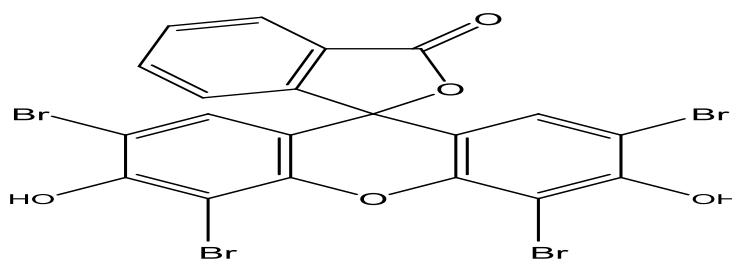


Figure 1. Chemical Structure of Eosin Dye

2. Materials and Methods

2.1 Chemicals

TiO₂ was supplied by Fluka AG and Eosin was supplied by sigma – Aldrich.

2.2. Photocatalytic degradation processes of Eosin dye using TiO₂:

The degradation process of Eosin has been investigated using the photo reactor. This reactor consisted of two parts. The first part has been used for cooling the Eosin solution using the running water which passed through it. The second part was the reaction solution vessel with (100 ml) capacity. The removal of the studied dye has carried out using mercury lamp (125 W). All experiments were carried out by mixing (0.1 gm) of the catalyst with (10 mg/L) of Eosin solution. The dye suspended solution was kept under stirring for (20 min) and was bubbled with air (10 ml/min) during the irradiation process. A (3 ml) of the reaction mixture was withdrawn every (10 min) and then centrifuged at (4000 rpm) to remove the catalyst. All samples absorption was measured by UV-Vis spectrophotometer [19,20].

3. Result and Discussion

3.1 Effect of Titanium Dioxide Mass on the Photocatalytic Degradation of Eosin

To study the effect of TiO₂ on the degradation of Eosin, (10 ppm) of this dye was used with (10ml/min) flow rate of air, and at (298 K) RT. Figure 2 represents photocatalytic degradation processes of Eosin at different loaded masses of titanium dioxide. Photocatalytic degradation of Eosin gradually increased as the mass of TiO₂ increased until it reached (0.1gm /100 ml), then gradually decreased. Because at the higher dosage of the catalyst, the light will scatter and only the solution layers located on the top will receive the light [21,22]. Furthermore, when the mass of TiO₂ is below (0.1gm /100ml) the photo degradation of Eosin also decreased. Because the surface area decreased and that gave less light absorption by the catalyst that led to less degradation of Eosin.

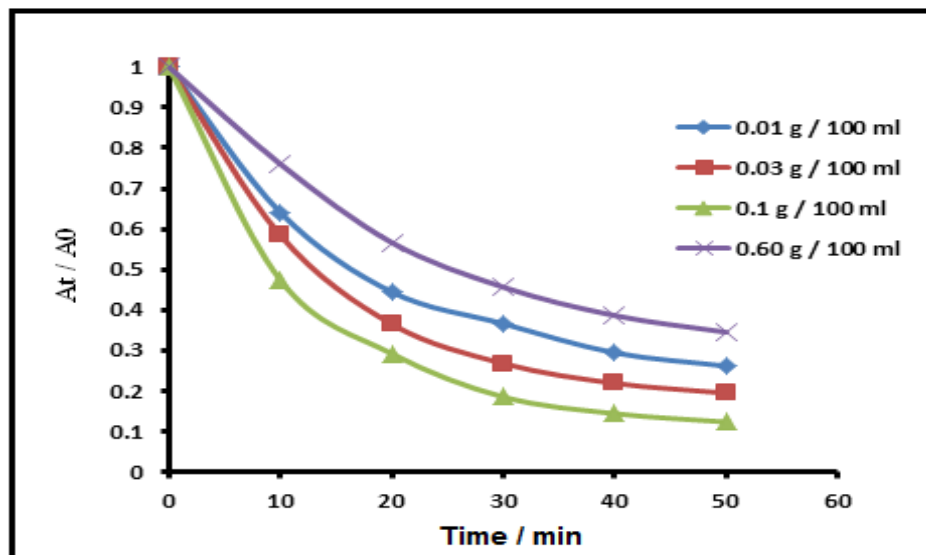


Figure 2. Effect of TiO₂ mass on the photocatalytic degradation of Eosin

Figure 3 shows the kinetic analysis for TiO₂. The graph of $\ln(A_0 / A_t)$ vs. time is a straight line through the origin. Therefore, the rate of photodegradation follows a first order law and the slope gives k (min^{-1}) [23].

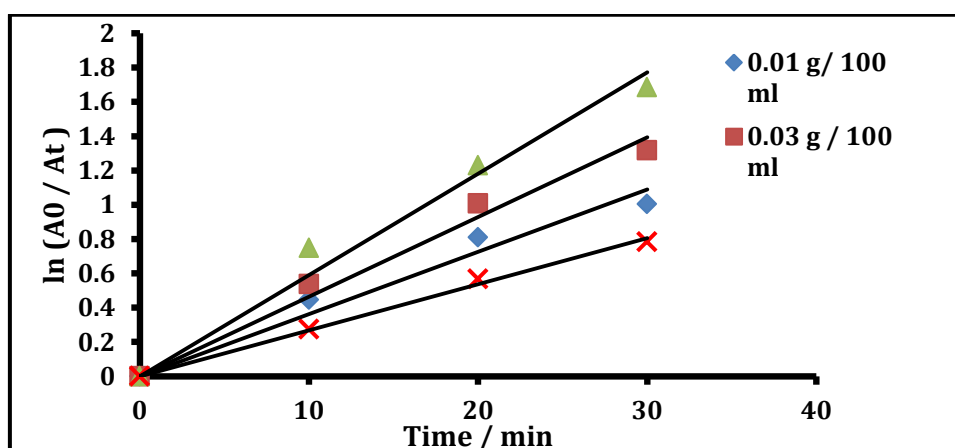


Figure 3. Relationship between $\ln(A_0/A_t)$ and irradiation time on different dosages of titanium dioxide

While, Figure 4 shows the relationship between the rate constant of the reaction and the loaded masses of the catalyst. It was found that the reaction rate constant increased when the loaded mass of the catalyst was increased until the reaction reached the optimum condition (0.1 gm/ 100 ml) [24].

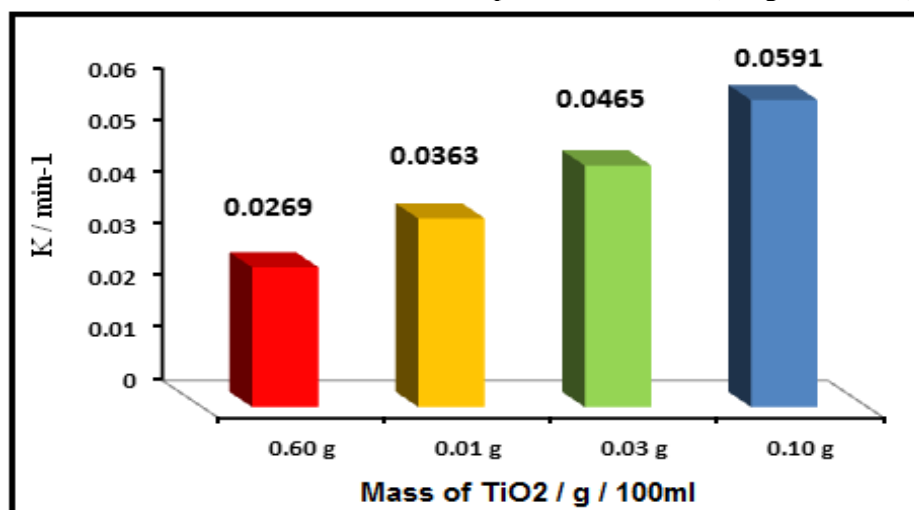


Figure 4. Relationship between rate constant and dosage of TiO_2

3.2 Effect of Eosin concentration on its photocatalytic degradation

Eosin with different concentrations (10 – 50) ppm were irradiated using TiO_2 (0.1gm / 100 ml), with the light intensity (8.22 mW/cm^2) and at room temperature. 'Figure 5' shows that the rate of the photocatalytic degradation gradually decreased when the Eosin concentration increased. Also, it shows that the best concentration of the dye was (10ppm). At this concentration a largest area of TiO_2 will be saturated with Eosin and this resulted in the absorption of more exciting photons. Moreover, the presence of excess dye will prevent the light to penetrate through the suspended solution, and this leads to decrease the photocatalytic degradation of Eosin on the catalyst surface [25, 26].

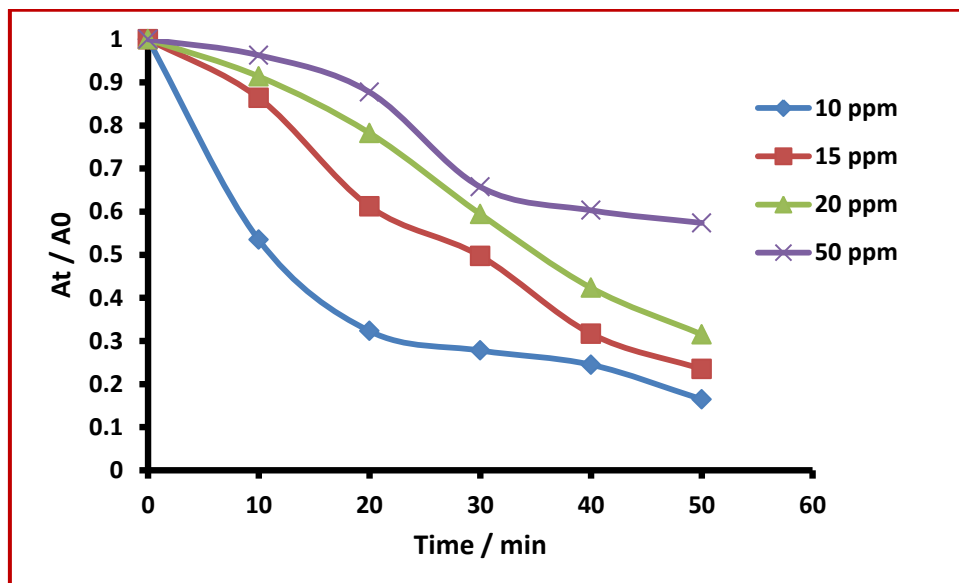


Figure 5. Relation between the change in (A_t / A_0) with irradiation time using various concentrations of Eosin

Figure 6 shows the kinetic analysis for TiO_2 . The graph of $\ln(A_0 / A_t)$ vs. time is a straight line. This figure also shows the photo degradation of Eosin dye which is in good agreement with the Langmuir-Hinshelwood model [27-29].

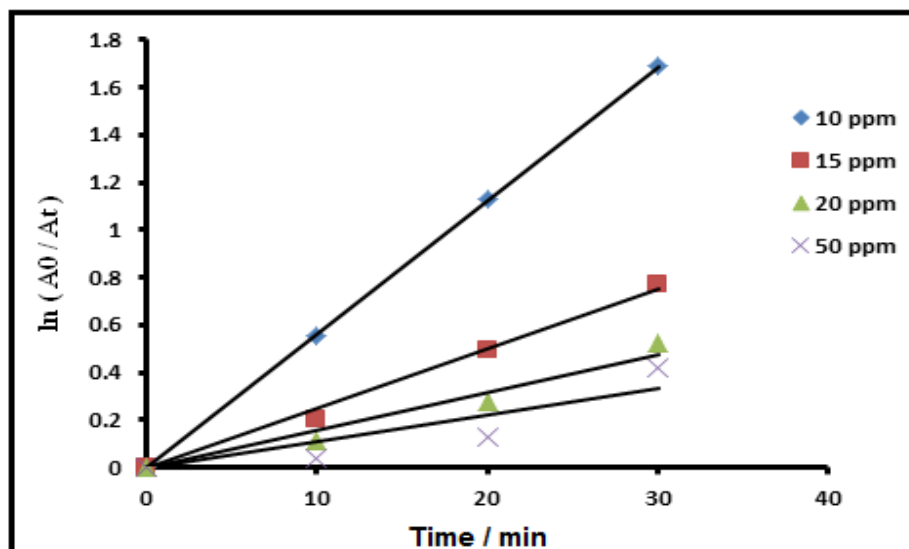


Figure 6. Relationship between $\ln(A_0 / A_t)$ and irradiation time on different concentration of Eosin dye

The high photo degradation efficiency (83.54%) was achieved when the Eosin concentration was (10 ppm). Figure 7 illustrates the photocatalytic degradation efficiency (P.D.E) with different concentrations of Eosin.

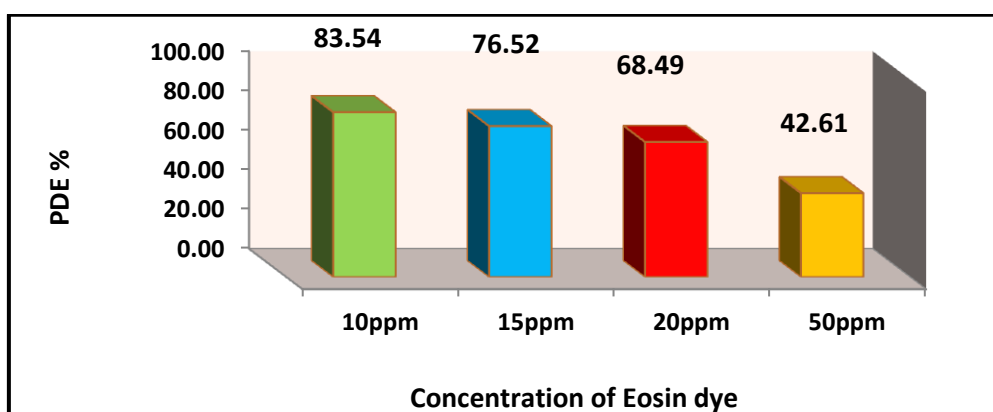


Figure 7. P.D.E of Eosin at various concentrations of the dye

4. Role of inorganic anions in Eosin photocatalytic degradation

Sodium chloride was used to study the effect of inorganic ions on the degradation of Eosin. Without any additions of this salt the degradation rate of Eosin was (91.77%) while, the rate decreased to (72.47%) when chloride ions were added (10 ml). This decrease in the photocatalytic activity is due to the scavenging of $\cdot\text{OH}$ radicals by these ions [30]. 'Figures .8 and 9'. show respectively the effect of the inorganic ions on Eosin degradation and the photodegradation efficiency of the dye using various concentrations of these ions.

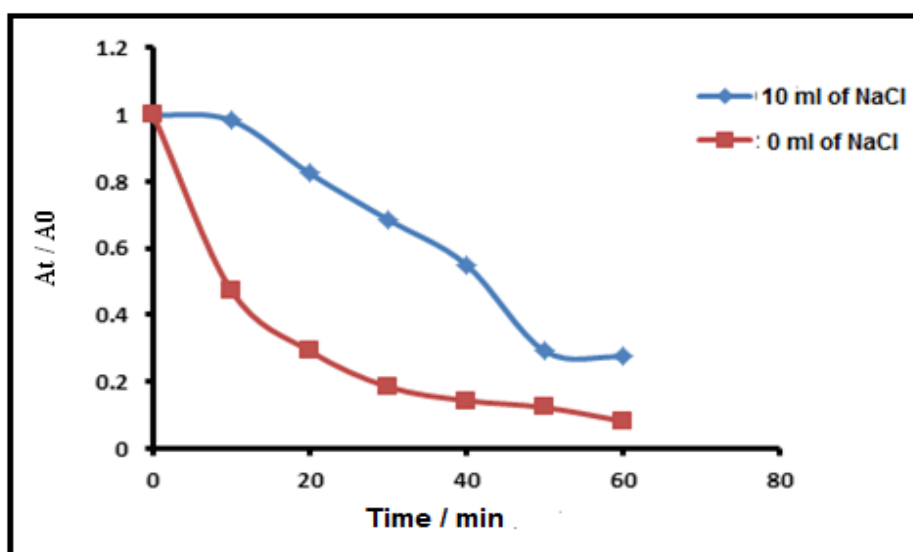


Figure 8. Effect of NaCl on the photocatalytic degradation of Eosin

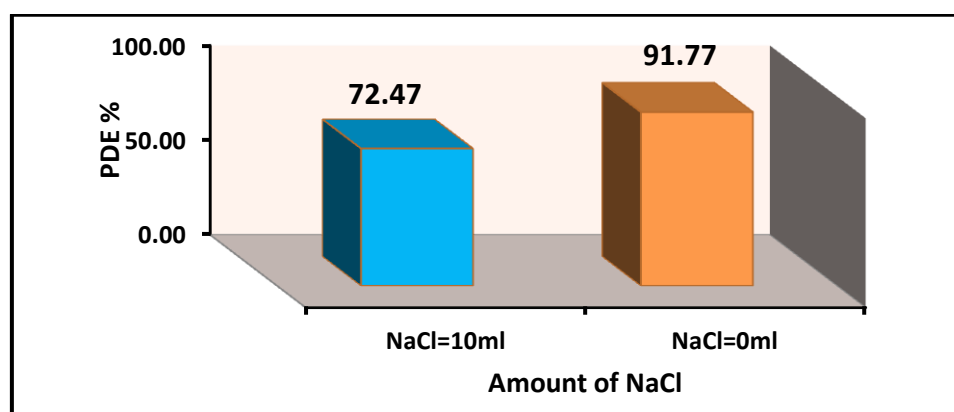


Figure 9. Photodegradation efficiency of Eosin with different concentrations of NaCl

5. Conclusion

The photocatalytic degradation process of Eosin depended on the mass of titanium dioxide where the optimum value was (0.1 gm/100 ml^l). In addition, the photocatalytic destruction of Eosin obeyed the pseudo-first-order reaction where, the degradation process decreased. This dropping is accompanied with increasing the concentration of Eosin which due to the decrease of the concentration of OH⁻ which adsorbed on TiO₂ surface and the dye concentration was (10 ppm) as an optimum value. Furthermore, the degradation process of the dye increased with the increase of light intensity because of the increase of photoelectron in the conduction band and this led to an increase in the electron-hole pairs number and a decrease in recombination process. The percentage of dye degradation was (91.77%) and (72.47%) in the absence and the presence of the inorganic ions respectively.

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