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Photo catalytic degradation of textile dyes: Model of the main reasons of positive and negative results

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A B S T R A C T

Due to the photocatalytic process's ability to use light energy to drive chemical processes, wastewater photolysis is commonly viewed as a green technology that can help humanity address the pressing environmental and energy issues facing human society. The liquid waste generated by the textile sector is still heavily polluted with toxic chemicals and colors. Organic pollutants, such as wastewater containing dyes, can be reduced using a process called photolysis.
Photocatalytic decolorization of aqueous solutions of methylene blue dye in the presence of TiO_2 was studied using an artificial UV-A light source. The effects of various factors were also studied, such as mass of catalyst (weight effect), concentration of MB dye, and measurement of light intensity. Decolorization cannot be done with absence of stimulus and/or light radiation. The process of dye decolorization follows pseudofirst-order kinetics. This study used UV-visible spectroscopy to explore the photodegradation of methylene blue dye by TiO_2 under UV irradiation.After that, the positive and negative results were compared by the researchers.

1. INTRODUCTION

Environmental problems are becoming a serious burden for everyone on the planet, since severe pollution and increased energy consumption have caused a lot of fear. Urbanization over time has undoubtedly contributed to environmental degradation due to the rising need for industrialization, which is posing a growing threat to all forms of life on Earth. Particularly the material initiatives, the dyes industry's wastewater is a significant source of water pollution. Aromatic-azo-dyes represent the majority of textile dye enterprises (65-75%) [1]. These pollutants pose a serious threat to the environment and public health as they are hazardous to humans, aquatic life, and microbes. Due to its superior stability, low cost, and environmental friendliness, researchers have been using it widely for photocatalytic wastewater treatment [2,3].The decomposition of a variety of organic pollutants, the elimination of harmful gases, and wastewater treatment are some of these uses. However, because of its wide band gap of 3.0-3.2 eV, it can only absorb light in the UV region, which reduces its effectiveness [4] . For its potential use in organic synthesis and environmental applications, heterogeneous photo catalysis employing oxide semiconductors has received a great deal of attention recently [5] .

The aesthetic effects and toxicity of textile effluents on receiving waters make their treatment of interest. Treatment reduces the threats to human and environmental health are decreased by preparing wastewater for discharge into natural water bodies.
Waste water containing dyes has been treated using a number of well-established methods, including membrane processes, chemical oxidation, microbial degradation, adsorption, and biosorption. The dyes are organically soluble compounds, classified as bases, acids, reactive and directly applied. The ability to fix the color in a material is attributed to auxotrophic groups, which are polar and can bind to polar groups of textile fibers. Nevertheless, this capability is not always present [6-8]. In recent years, the dye business has experienced substantial growth. The number of commodity dyes has reportedly reached the tens of thousands, according to the US "Color Index". Every

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year, 60,000 tons of colored trash are dumped into the environment [9], with azo dyes accounting for 80% of this amount [10-13] . The majority of synthetic dyes utilized in the textile and other industries are called azo dyes (contain azo chromophore).

The concentration of azo dye in wastewater ranges from 5 to 1500 mg/L due to the textile industry's inadequate dye fixing practices [9,14-16]. Studies have shown that an excited semiconductor can destroy the dangerous organic compounds in waste water by employing photo excited charge carriers. To get rid of this textile dye contamination, various different degrading techniques have been suggested. Oxidation photocatalytic degradation employs (TiO_2) [17]. In this work: There are two types of errors: researcher errors and automatic errors, which led to negative results.In addition, we have repeated the same experiment, and we have gotten positive results. The degradation of textile dye by TiO_2, which is lit by UV, has been demonstrated in a prior study to take place within 1.5 hours.

2. METHODS AND MATERIALS

Sigma-Aldrich supplied commercial TiO_2 powder in Germany, whereas the Iraqi Hilla Company of Textile Dyes supplied Methylene Blue Dye (MB) [18], as seen in figure(1). This study employed analytical-grade chemicals without any additional purification. The stock solution utilized in this study contained 1000 mg/L of MB.

Figure 1. The MB dye molecule's model and structure (18).

Photocatalytic experiment

A handmade photo reactor was used in an experimental setting to perform photocatalytic degradation. Irradiation sources (Philips mercury lamp UV(A), with 6 W lights). The majority of experiments were conducted in a 400 cm3 reactor. The distance between the lamp and the radiation vessel was fixed for a particular light intensity. The lamp was positioned perpendicularly above. All studies involved using a magnetic stirrer to suspend the necessary amount of photocatalyst in 200 cm^3 of aqueous dye solutions. Most samples were centrifuged in a JANETZI-T5 (Belgium) at 6000 rpm for 10 minutes. When the initial tests provided unfavorable outcomes, the supernatant was carefully extracted using a syringe with flexible, expanded needle, centrifuged again, and the tests were repeated with the supernatant being centrifuged for the same amount of time and rate (positive results). A third centrifugation was essential to remove the beneficial, minute amounts of (TiO_2), according to analysis by (UV-Visible) spectrophotometer. A (UV-Visible) spectrophotometer [(Type Shimadzu, Japan, PC 1650-303] was used to measure the dye concentration. The temperature used for all tests was 298 K.

Blue Dye (MBD) from Sigma-Methylene Aldrich [C16H18CIN3S, Purity 99.0%] TiO_2 was in an aqueous dye solution containing 50 ppm, as cationic dye models were utilized to test the photocatalytic activity. The suspension was magnetically agitated for 90 minutes in the dark before being exposed to radiation, in order to establish an equilibrium between the dye and the adsorption and desorption processes of the catalyst. Every (15) minutes during the testing, roughly (5) ml of samples were taken. In order to separate the suspended solid particles, a centrifuge was used. The remaining dye was using a UV-visible spectrophotometer content in an MBD solution kept in a micro-cuvette (Perkin-Elmer Lambda 25) at 663 nm, with an account to R.O. water (figure 2).

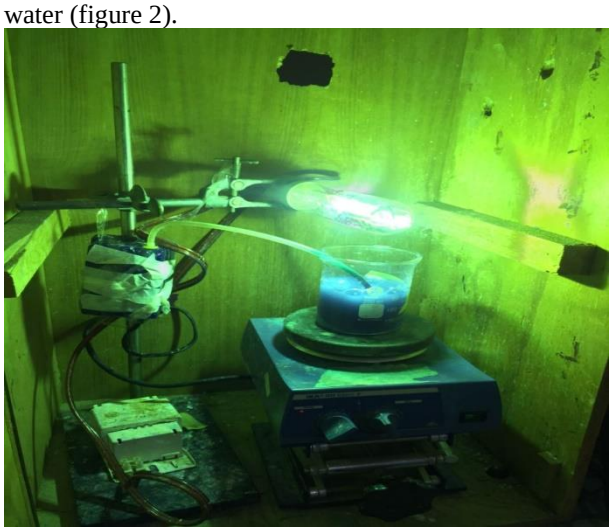


Figure 2. Photo-degradation of real image sample M.B dye and TiO_2 NPS.

Equation (1) below was used to compute the deterioration efficiency:

Photocatalytic. Degradation .Efficiency (PDE%) = $\frac{C0-Ct}{C0}$ x 100 ---------(1)

Where Co is the initial dye concentration and the dye concentration (Ct) is measured after the testing period (t)(7).

3. THE RESULTS AND DISCUSSION

Effect of mass dosage

Effects of the photocatalyst concentration (0.2-0.4.0.6.0.8) gram during 1.5 hours and reaction temperatures of 25 °C, on the photocatalytic degradation of (MB) dye. As demonstrated in figure 3 (a) and (b), the experimental results could be evaluated via assuming. The findings were discussed using a pseudo-first order kinetic model.

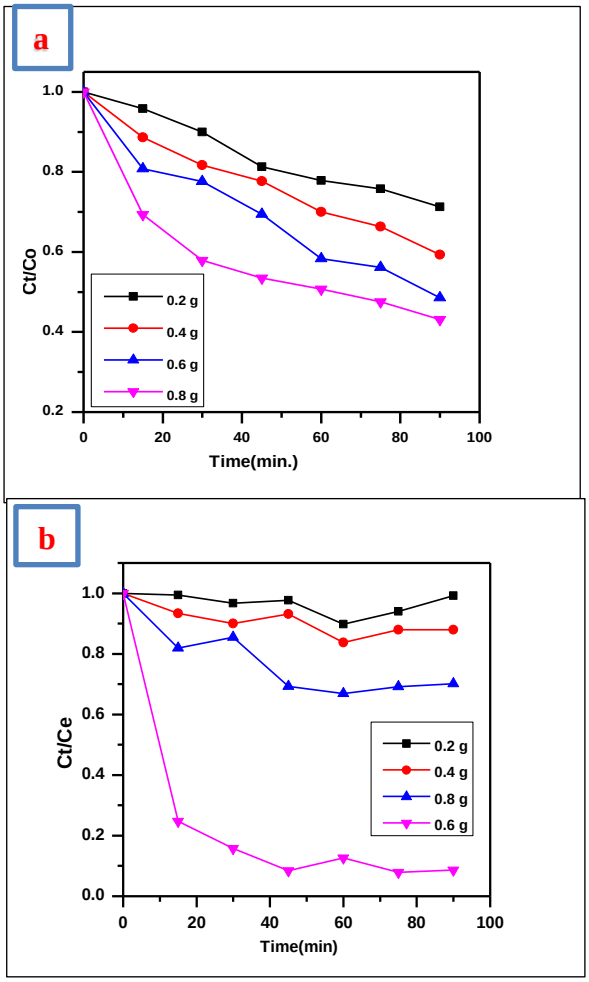


Figure 3. At various mass dosages, photocatalytic degradation of MB dye produced both (a) posative results and (b) negative results.

As seen in figure (3), the amount of adsorbent used has an effect on the elimination of 50 mg/L of MB dye. After 1.5 hours of degradation, the removal percentage improved with an increase in mass dosage of (0.2 - 0.8) gm (20.76 - 32.75%) for positive results and (18.20- 3%) for negative results, this study is in agreement with Reza, Khan Mamun, and other studies (2017). They discovered that the proportion of degradation falls when the dye's initial concentration is increased. Moreover, the dosage of TiO_2 can impact the rate of deterioration [17], Wei and Wan (1991) found that the amount of catalyst had both positive and negative effects on the rate of photodecomposition [18]. There was a heterogeneous regime since the first reaction rates were demonstrated to be precisely proportionate to the concentration of the catalyst.

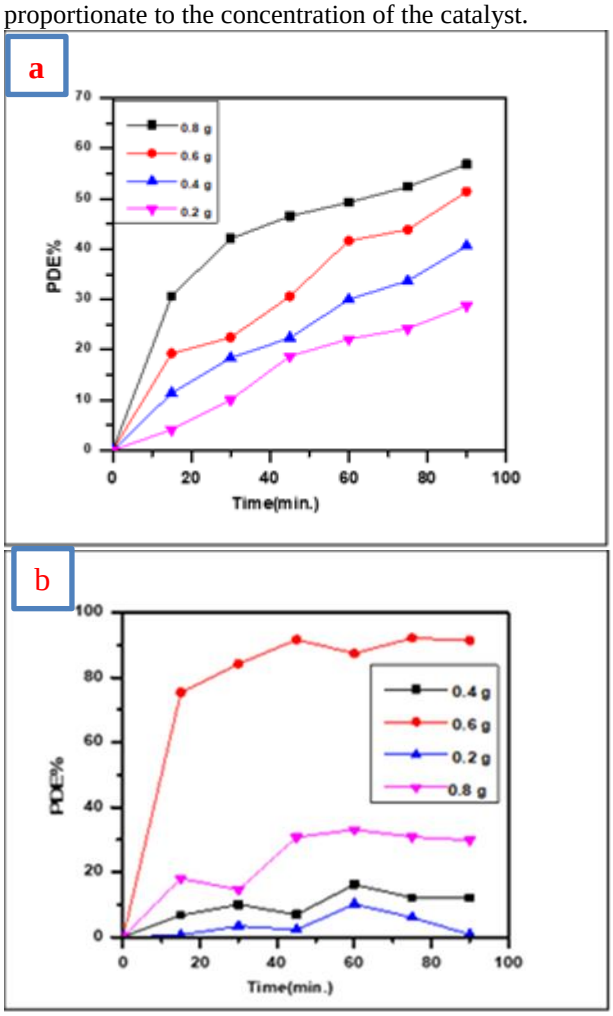


Figure 4. (a) posative and (b) negative results: Explained the efficiency of (0.2-0.4.0.6.0.8) gram on the PDE of (MB)dye

Effect of MB dye concentration

To examine how photocatalyst concentration affected the rates of degradation, different amounts of degussa P25 in the range of 0.5–5 g/l were used. Figure (4),[19, 20].

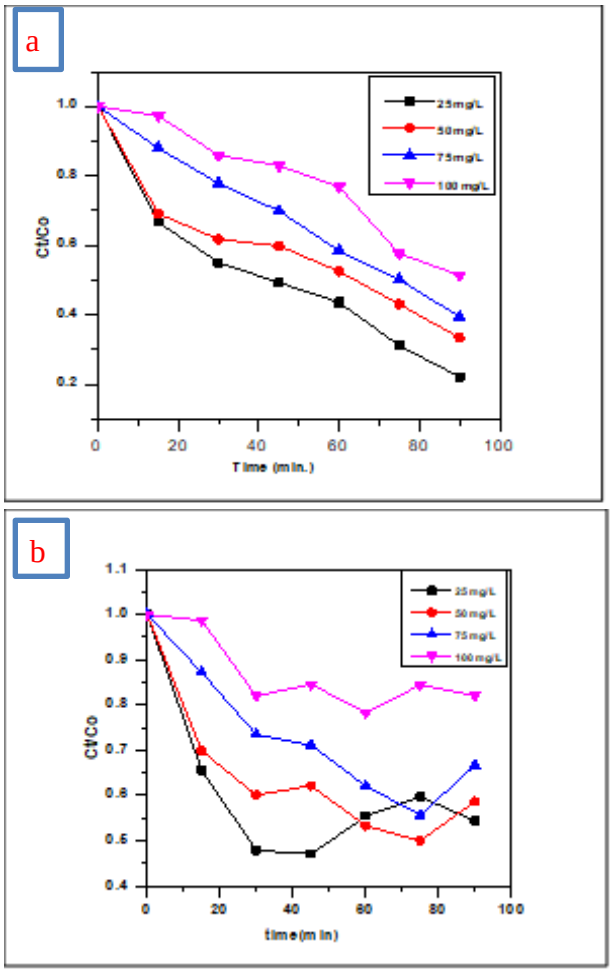


Figure 5. (a)- Positive and (b)- Negative results of dye MB's photocatalytic degradation at various basic condition.

In figure (5) different MB (10-100) ppm concentrations were selected in order to examine the effects of the dye's starting concentration on TiO_2. In figure 4, a mass dosage of 0. 6 gm is shown. The main dye solution component has a considerable impact on how quickly MB degrades. The photocatalytic degradation of dye with respect to time and concentration. As illustrated in figure 4, the experimental results could be evaluated assuming first order kinetics (a). and Figure. (5) shows no outcomes (b). This is because the outcomes were bad [3, 21].

Effect of solvent

The MB dye is photolyzed in the atmosphere, hence oxygen is necessary for the degradation to occur. •OH radicals are produced by the monoelectronic reduction of MB+ radicals by OH in basic media. CO_2, a key active species in degradative processes, is created when OH reacts with one another. Similar to how O_2 reacts with excited MB* radicals, O_2• is created. Equations (2)
through (4) characterize these MB photolysis reactions as follows [22]:

$MB+ + OH- \rightarrow MB^* + OH\bullet$ --------(2)

$2OH\bullet \rightarrow H_2O_2$ -------- (3)

$MB^* + O_2 \rightarrow MB+ + O_2\bullet-$ ------- (4)

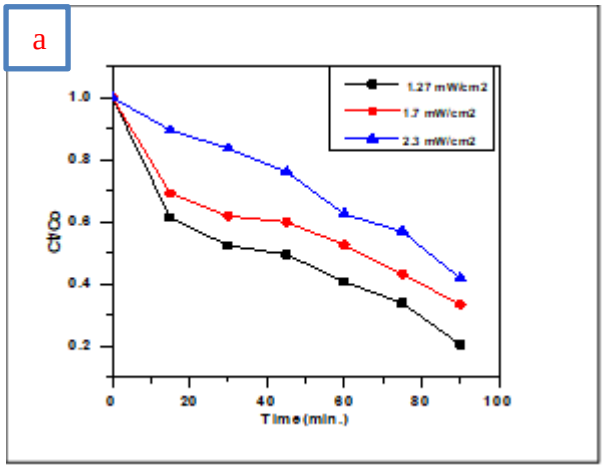
Direct photolysis of MB dye occurs as a result of the involvement of all these reactive radical species. Equations (5) can be used to determine the photodegradation of MB dye in percent.

Rate of Degradation (%)= (C0-Ct)/C0 ------ (5)

By rerouting light photons away from the photocatalyst's surface and limiting the availability of oxidative free radicals, the elevated MB concentration may function as an inner filter. The reason why MB photodegrades less slowly at larger concentrations is thought to be due to the increased dye molecules' adsorption on photocatalyst active sites, which inhibits the generation of active •OH radicals and increases the UV light's screening effect [23].

Effect of light intensity

light of higher intensities, photodegradation efficiency increase and reaction rates speed up [24] and, by altering the distance between the light source and the semiconductor's exposed surface, it was possible to determine the impact of light intensity (2.3-1.7-1.27) $mWcm^{-2}$) on both favorable and negative findings. In the presence of a catalyst, the effect of light intensity on dye photodegradation was investigated (0.6 g/L^{-1}, 50 ppm dye)., as seen in figure. 5-(a).Further more, it was observed that all reactions continued to follow first-order kinetics with no results in figure. 5-(b) because of the unfortunate outcomes.



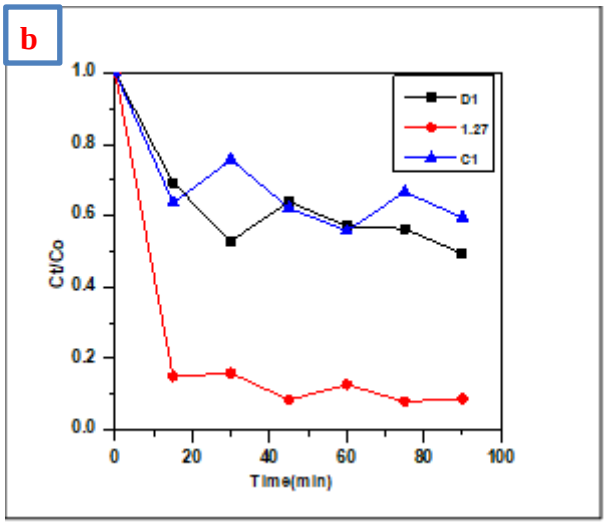


Figure 6. (a) posative and (b) negative results : Explained the effect of light intensity on MB dye

Wei and Wan (1991) showed that the amount of catalyst has a positive and negative effect on the rate of photodecomposition. Their findings are supported by this work. The investigation by Groeneveld, Iris, and their colleagues in 2022 revealed that:

(i) Because the quantum efficiency, or the ratio of photons converted to absorbed, is constant and changes with intensity, when light intensity are modest, the relationship is linear.

(ii) Unlike the following, the rate is based on the square root of the light intensity above a particular threshold of intermediate light intensities.

(iii) At high light intensities, the photodegradation rate is constant and unaffected by light intensity [25].

4. CONCLUSIONS

In this work: there are two types of errors: researcher errors and automatic errors, which led to negative results. Also, the researcher errors: The experiments in which the researcher used the insufficient centrifuge,led to the remaining particles that affected the absorbency and the automatic errors are that the UV-Visible spectrometer device is sensitive to everything in the cell, so the particles that affected this appeared. In addition, according to the data, dye MB can be successfully degraded in aqueous dispersions with the help of a TiO_2 aided technique. High intensity light and low primary concentration were the ideal circumstances for the photocatalytic breakdown of dye MB (promising results). Due to the two sorts of errors mentioned above, outcomes when there are none are found to be negative.

Acknowledgements

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Arabic Abstract

نظرا لقدرة عملية التحفيز الضوئي على استخدام الطاقة الضوئية لدفع العمليات الكيميائية، يُنظر عادةً إلى التحلل الضوئي لمياه الصرف الصحي على أنه تقنية خضراء يمكن أن تساعد البشرية في معالجة القضايا البيئية والطاقة الملحة التي تواجه المجتمع البشري. ولا يزال تلوث النفايات السائلة الناتجة عن قطاع النسيج بشكل كبير بالمواد الكيميائية والألوان السامة موجود لحد الان ، ويمكن تقليل الملوثات العضوية، مثل مياه الصرف الصحي التي تحتوي على الأصباغ باستخدام عملية تسمى التحلل الضوئي .

تمت دراسة إزالة اللون بالتحفيز الضوئي للمحاليل المائية لصبغة الميثيلين الزرقاء في وجود TiO_2 باستخدام مصدر ضوء UV-A الاصطناعي, وكذلك تمت دراسة تأثيرات العوامل المختلفة، مثل كتلة المحفز (تأثير الوزن) ، وتركيز صبغة MB، وقياس شدة الضوء، ولا يمكن إزالة اللون في غياب المحفز /أو الإشعاع الضوئي. تتبع عملية إزالة اللون من الصبغة حركية الدرجة الأولى الكاذبة. استخدمت هذه الدراسة مطياف الأشعة فوق البنفسجية المرئية لاستكشاف التحلل الضوئي لصبغة الميثيلين الزرقاء بواسطة TiO_2تحت إشعاع الأشعة فوق البنفسجية , وبعد ذلك تمت مقارنة النتائج الإيجابية والسلبية من قبل الباحثين .