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Treatment of industries wastewater using solar light

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Abstract. The degradation of eosin yellow dye using ZnO as a photo catalysts in a slurry reactor exposed to solar light was studied by this paper. The optimum values of different parameters versus catalyst concentration, catalyst type and initial concentration of the substrate affecting the degradation rate of eosin yellow dye were obtained by varying catalyst concentration (255–1255 ppm), and initial dye concentration (25–100 ppm). Color disappearance as well as substrates with the depletion of total organic carbon content was monitored.

Keywords: Solar light; eosin yellowish dye; Photocatalysis; Zinc oxide

1. Introduction

The degradation of organic pollutants in water by catalytic photovoltaic processes have been subjected to extensive research recently. The high photosensitivity, non-toxic nature, low cost and chemical stability of semiconductor oxides have recognized them as preferable components for catalytic photovoltaic processes. The semiconductor or photo catalysis is initiated by the surface trapping of photo-generated electrons (e⁻) and holes (h+), which induces interfacial electron-transfer reactions with adsorbed substrates. However, because of the wide band gap of ZnO and TiO₂ [1-3]. Solar Energy treatment is very important method used in this field because it is very cheap and available in most of world countries we can say it is future energy. The adoption of solar photocatalytic reactors to treat textile processes wastewater is potentially viable in geographical areas receive heavy flux of sunlight over the year [4]. And Iraq is a potential to introduce similar technology. Its reported that dyes absorb light highly within visible range, the summation of energy efficiency should be feasibly high in order to make the photo-assisted treatment of dye-polluted wastewater achievable [5,6]. Eosin yellowish was used as one of the most important dyes because of it is emotional-state lifetime which was considerably short. Moreover, It was visibly constant and in addition, It provides a helpful investigation for the both of removal of photo reactions and oxidation [7]. For the oxidation reaction about photo of Eosin yellowish in a slurry reactors and TiO₂ immobilized reactors, most studies had been made [8,9]. Estimating the execution of a fluidized bed photo catalytic reactor in a three-phase have been tested by previous studies and significant information were obtained. The photocatalytic degradation of eosin yellowish dye in aquatic solutions using two different photocatalysts had been examined. The major aims of the study were (a) effect of catalyst concentration; (b) effect of pH. (c) effect of initial dye concentration; (d) studies kinetic of reaction.

2. Experimental work

2.1. Materials

ZnO powder was used in this experiment and were gained from Merck Co. (Germany), eosin yellowish dye was bought from Merck (Germany) and was used without further treatment. Different solutions were prepared by using distilled water.
2.2. Instruments
Photo-chemical degradation was conducted by employing an especially designed insulation walled containers with volume of 500 ml. Continuous stirring while samples are exposed to solar light were achieved by magnetic stirrers. Temperature was maintained constant during the reaction by wetting the photo catalytic reaction vessel by water.

2.3. Irradiation experiments
Suspension of 0.25 l of the dye solution and photo catalyst was prepared and the mixture was exposed to irradiation. Experiments were conducted under solar light. The aqueous suspension was magnetically stirred over the experiment. At different time periods, an aliquot was obtained by using a syringe and so filtered through Millipore syringe filter paper of 0.45 µm.

2.4 The Measurements of Absorption
A Double Beam UV-1800 (Shmadzo spectrophotometer) was used to record absorption spectrum and then compared with distilled water as a reference liquid and the percentage rate of degradation was noticed in terms of change in intensity at $\lambda_{\text{max}}$ of the dyes during irradiation time. The degradation efficiency (%) has been calculated as:

$$\text{Degradation} \, (\%) = \frac{\text{Abs}_0 - \text{Abs}_t}{\text{Abs}_0} \times 100$$

Where Degradation (%) is percentage of dye disappearance, Abs 0 is initial absorption of dye (at time = 0 min.) and Abs t is absorption of dye (at time = t min.)

Similar experiments have used different catalyst concentration (250–1250 ppm), to select the best concentration of catalyst ZnO at the same concentration of the dye with the solution (25 ppm).

3. Results and Discussion

3.1 Effect of Photo catalyst Concentration
The catalyst concentration effect on the degradation of Eosin yellowish (25 ppm) was examined by using commercial ZnO from 250 to 1250 ppm maintaining other parameters such as dye concentration, pH and temperature). Figure 1 showed that the degradation percentage is subject to increase in ZnO commercial concentration up to 0.75 g/l for ZnO. This change in the degradation percent could be explained by active sites available on the catalyst surface and the permeation of solar light into the suspension. The total active surface area is increased with any increasing the dosage of the catalyst. On other hand, due to suspension turbidity increase , there is a reduction in solar light permeation because of increased scattering effect and hence the photo activated volume of suspension decreases. Furthermore, at high catalyst loading, it was observed that maintaining the suspension homogenous was difficult due to particles agglomeration, which decreases the number of active sites [10-13]. The results showed the highest value of photo degradation for commercial ZnO (750 ppm) achieved after 90 minutes.
3.2 pH Effective on Solution Treatment

The effluent on any type of wastewaters is produced at different pHs. So, study of pH is very important on photo degradation of Eosin yellowish dye. Experiments have been done at different values of pH varying from 3 to 11 for 25 ppm dye solution concentration and for the best concentration of the catalyst (750) ppm of ZnO. The photo degradation percentage against values of pH was showed in Figure 2. It is clearly increasing in pH up to 10 for ZnO because increasing in photo degradation activity [14]. The utilizing of ZnO as the catalyst is more appropriate at high pH values with the textile effluent; Textile industry processes are among the most environmentally unsustainable industrial processes [15-19]. Its complex to interpret the effect of pH on decolonization efficiency because many reactions can result in dye degradation such as “hydroxyl radical reaction, direct oxidation by the positive hole and direct reduction by the electron in the conducting band”. The importance of each one depends upon the substrate nature and pH.
3.3 **Dye Concentration effect**

The photo degradation of Eosin yellowish was conducted by increasing the initial dye concentration from 25 ppm to 125 ppm. This step was conducted in order to find out the effect of initial concentration of the dye on the most effective catalyst kind and dose (commercial ZnO). Because the concentration of the dye was enhanced, the share of degradation reduced indicating that either to extend the catalyst concentration or time span for the entire reduction. Figure 3 depicts the time-dependent graphs of degradation of Eosin yellowish at different dye solutions (25–125 ppm). A 100% degradation took place within 90 & 150 minutes respectively when using dye solutions of 25 ppm and 150 ppm. However, when using 150 ppm, it took almost 300 minutes for accomplished degradation of the dye. The degradation percentage rate had further minimized when the dye concentration was increasing. The reason behind this behavior was the path length of the light photons entering the solution was reduced in high dye concentration. In other words, the photochemical reaction is tend to reduced but the number of photons absorbed by catalyst is high at low initial concentration of the dye concentration the amount of photon absorption by the catalyst in lower [19-25].
3.4 Kinetic Study
Mechanism kinetic of dye degradation is shown by figure 4 (at optimum conditions). The results show that the disappeared of Eosin yellowish dye with zinc oxide with 1 g/l dose can be write by the following mathematical equation:-

\[
\frac{C_0}{C} = k t
\]

Where \(C_0\) is feed dye concentration, \(C\) is dye concentration at time \(t\), \(y=0.0422x\), \(k\) is equation constant and \(t\) is degradation time. The result data of the concentration with degradation time is gave a straight line and \(R^2 = 0.9231\) (correlation factor) for the ZnO [26-28].

3.5 Mineralization studies
Since the decrease of chemically demanded oxygen (COD) in water reflects that degradation reactions or mineralization of the organic components have take place. The removal percentage of COD was studied in case of initial concentration-25 ppm for dye samples by using optimized conditions of dose of catalyst of 0.75 g/l and a value of pH 9 as a function of irradiation time. It was found that after 20 minutes the removal COD percentage falls in the ranges of 85% and 90%. (see Figure 5). The percentage discoloring was higher than reduction of COD which could be explained by the formation of smaller colorless compounds. Therefore, it is quite evident that longer irradiation time is required in order to achieve complete mineralization of dyes.
**Figure 4.** Kinetic study of the disappearance of Eosin yellowish dye

\[ y = 0.0422x - 0.582 \]

\[ R^2 = 0.9231 \]

**Figure 5.** Comparison between percentage of discoloring and percentage COD reduction for eosin yellowish dye
3.6 Possibility of ZnO Reuse

The possibility of reusing ZnO for discoloring of Eosin yellowish dye was experimented. The solutions resulting from the photo catalytic discoloring of dye dried after filtering and washing the sample. The dried catalyst samples were used for the discoloring of dye solutions employing similar experimental conditions. It was found that considerable photo catalytic activity up to four cycles was shown by the sample. The activity of the sample tended to weakness to the extent of (8 – 10)% only after the forth trial. Calculation of Zn$^{2+}$ ions in the solutions was done to determine the loss of Zn$^{2+}$ ions within the solution as a result of dissolution of ZnO at alkaline pH (pH 9). The dissolution of ZnO was found to be negligible. Similar findings are reportable within the literature that no photo corrosion of ZnO takes place in alkaline conditions [27,28]. These results detect the stability of the prepared catalyst.

4. Conclusions

The photo catalytic degradation of aqueous solutions of Eosin yellowish dye has been examined by using a solar light-irradiated and ZnO catalyst. It has been found that the process leads to discoloring and, eventually to complete mineralization of the dye solution. Discoloring of the Eosin yellowish dye and finally complete consumption of the dye solution were achieved by the process. Mid and final products on the photo catalyst surface and the solution were monitored with various technologies that allowed the reaction pathways from adsorption of the dye molecules on the photo catalyst surface to the formation of the final product to be determined.

References

[1] Sakthivel S, Neppolian B, Shankar M V, Arabindoo B, Palanichamy M and Murugesan V 2003 Solar photocatalytic degradation of azo dye: comparison of photocatalytic efficiency of ZnO and TiO$_2$ Sol. Energy Mater. Sol. Cells 77 65–82.

[2] Evgenidou Fytianos E K and oullos I P 2005 Semiconductor-sensitized photodegradation of dichlorvos in water using TiO2 and ZnO as catalysts Appl. Catal. B: Environ. 59 81–89.

[3] Daneshvar N, Aber S, Seyed Dorraj M S, , Khataee A R and Rasoulifard M H 2005 Photocatalytic degradation of the insecticide diazinon in the presence of prepared nanocrystalline ZnO powders under irradiation of UV-C light, Sep. Pur if. Technol. 58 91-98.

[4] Bousselmi L, Geissen S U and Schroeder H 2004 Textile wastewater treatment and reuse by solar catalysis: results from a pilot plant in Tunisia. Water Sci. Technol. 49 331–37.

[5] Vinodgopal K, Wyncoop D and Kamat P 1996 Environmental photochemistry on semiconductor surfaces: photosensitized degradation of a textile azo dye, acid orange 7, on TiO2 particles using visible light. Environ. Sci. Technol. 30 1660–66.

[6] Nasr C, Vinodgopal K, Fisher L, Hotchandani S, Chattopadhyay A K and Kamat P V 1996 Environmental photochemistry on semiconductor surfaces, Visible light induced degradation of a textile diazo dye, Naphthol Blue Black, on TiO2 nanoparticles. J. Phys. Chem. 100 8436–42.

[7] Lathasree S, Nageswara R, Sivasankar B, Sadasivam V and Rengaraj K 2004 Heterogeneous photocatalytic mineralization of phenols in aqueous solutions. J. Mol. Catal. A Chem. 223 101–105.

[8] Daneshvar N, Salari D and Khataee A R 2004 Photocatalytic degradation of azo dye acid red 14 in water on ZnO as an alternative catalyst to TiO2. J. Photochem. Photobiol. A Chem. 162 317–22.

[9] Chen L C 2000 Effects of factors and interacted factors on the optimal decolorization process of Eosin yellowish by ozone. Wat. Res. 34 974–82.
[10] Zhu C, Wang L, Kong L, Yang X, Wang L, Zheng S, Chen F, Maizhi F and Zong H 2000 Photocatalytic degradation of azo dyes by supported TiO2 and UV in aqueous solution. Chemosphere. 41 303–309.

[11] Kansal S K, Ahmed Hassan Ali and Kapoor S 2010 Photocatalytic decolorization of biebrich scarlet dye in aqueous phase using different nanophotocatalysts. Desalination 259 147–55

[12] Konstantinou I K and Albanis T A 2004 TiO2-assisted photocatalytic degradation of azo dyes in aqueous solution: kinetic and mechanistic investigation. Appl. Catal. B: Environ. 49 1–14.

[13] Ali A H, Naser G F and Mohammed S A 2016 Photocatalytic Degradation of Methyl Orange Dye using Different Photocatalysts under Solar Light. Internat. J. ChemTech Res. 910.

[14] Lizama C, Freer J, Baeza J and Mansilla H D 2002 Optimized photodegradation of reactive blue 19 on TiO2 and ZnO suspensions. Catal. Today 76 235–246.

[15] Hussein A and Scholz M 2017 Dye wastewater treatment by vertical-flow constructed wetlands. Ecol. engin. 101 28-38.

[16] Hussein A and Scholz M 2017 Treatment of artificial wastewater containing two azo textile dyes by vertical-flow constructed wetlands. Environ. Sci. and Poll. Res. 1-20.

[17] Hussein, A. 2017. Azo textile dyes wastewater treatment with constructed wetlands: design and operation of experimental vertical-flow constructed wetlands applied for the treatment of azo textile dyes (with/without artificial wastewater)(Doctoral dissertation, University of Salford).

[18] Hussein A M 2018 constructed wetlands for treatment azo textile dyes wastewater (Mauritius: LAP LAMBERT Academic publishing) p 293

[19] Ali. A H 2017 Preparation and Characterization of Nanoparticles TiO2 and Its Application for Methylene Blue Dye Degradation under Solar Light. J. of Glob. Pharma Techno. 9 141-48

[20] Rabindranathan S, Suja D P and Yesodharan S 2003 Photocatalytic degradation of phosphamidon on semiconductor oxides, J. Hazard. Mater. B. 102 217–29.

[21] Chan A H C, Porter J F, Barford J P and Chan C K 2002 Effect of thermal treatment on the photocatalytic activity of TiO2 coatings for photocatalytic oxidation of benzoic acid, J. Mater. Res. 17 1758–65.

[22] Styliadi M Kondarides D I and Verykios X E 2003 Pathways of solar light-induced photocatalytic degradation of azo dyes in aqueous TiO2 suspensions, Appl. Catal. B: Environ. 40 271–86.

[23] Sakthivel S, Neppolian B, Shankar M V, Arabindoo B, Palanichamy M and Murugesan V 2003 Solar photocatalytic degradation of azo dye comparison of photocatalytic efficiency of ZnO and TiO2. Sol. Energy Mater. Sol. cell. 77 65-82.

[24] Chakrabarti S and Dutta B K 2004 Photocatalytic degradation of model textile dyes in wastewater using ZnO as semiconductor catalyst, J. Hazard. Mater. 112 269–78.

[25] Wang H, Xie C, Zhang W, Cai S, Cai Z, Yang Z and Gui Y 2007 Comparison of dye degradation efficiency using ZnO powders with various size scales, J. Hazard. Mater. 141 645–52.

[26] Ali A H, Naser G F and Alkaim A F 2018 Treatment of Textile Industries Wastewater by Advance Oxidation Process. J. Eng.Appl. Sci. 13 1042-45.

[27] Daneshvar N, Solari D and Khataee A R 2003 Photocatalytic degradation of azo dye acid red in water: investigation of the effect of operational parameters, J. Photochem. Photobiol. A: Chem. 157 111–16.

[28] Shankar M V, Anandan S, Venkatachalam N, Arabindoo B and Murugesan V 2004 Novel thin-film reactor for photocatalytic degradation of pesticides in aqueous solutions, J. Chem. Technol. Biotechnol. 79 1258–79.