

UV –Induced Removal of Acid Red 18 in Water On ZnO as an Alternative Catalyst to TiO₂

Jila talat mehrabad^{1,*}, Nasim ziaifar ², Farzad arjomandirad³

^{1,*} Department of Chemistry, Faculty of science, Islamic Azad University, Bonab Branch, Bonab Iran.

² Department of Chemistry, Faculty of engineering, Islamic Azad University Maragheh Branch, Maragheh Iran.

³ Department of Chemistry, Faculty of science, Islamic Azad University, Bonab Branch, Bonab Iran

ABSTRACT

Textile wastewaters are known as an important environmental pollutant. The main characteristic of textile wastewater is its colorness, which contains various organic and inorganic pollutants. The nanophotocatalytic process using nano-structured semiconductors is one of the techniques used for the destructive oxidation of organic compounds such as dyes. The photocatalytic oxidation of acid red 18 aqueous solution, applied in the textile industry, was assessed by UV ray irradiation in the presence of TiO₂ nanoparticles. In this study, a detailed investigation of photocatalytic degradation of acid red 18 is presented. The effects of some parameters such as pH, amount of photocatalyst, hydrogen peroxide and radiation intensity were also examined. The best results of dye degradation were reported in concentration of 145 mg/L ZnO nano-particles and the radiation intensity of 240 μW/cm². Rate of dye removal was decrease with increasing of color concentration.

KEY WORDS: TiO₂; photocatalysis; Azo dyes; Acid red 18; Zinc oxide.

1. INTRODUCTION

The textile industry produces large quantities of highly colored effluents, which are generally toxic and resistant to destruction by biological treatment methods. Acid Red18 (AR18) is a acidic dye, which is soluble in water and has a structure as figure 1. [1,2]

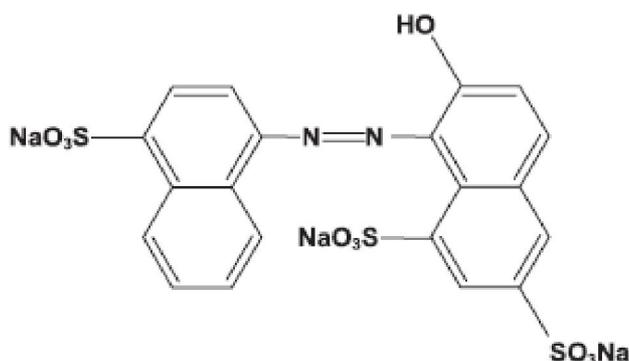


Figure1. structure of Acid red18

Advanced oxidation processes (AOPs) are the methods in which OH• radicals are produced. mechanism of Hydroxyl radicals (HO•) are effective in destroying organic chemicals because they are reactive electrophiles (electron preferring) that react rapidly and nonselectively with nearly all electron-rich organic compounds. [3,4] They have an oxidation potential of 2.33 V and exhibit faster rates of oxidation reactions comparing to conventional oxidants such as H₂O₂ or KMnO₄. [5] AOPs include photocatalysis systems such as a combination of a semiconductor (TiO₂, ZnO, etc.) and UV light. [6]

In TiO₂/UV light process, a titanium peroxide semiconductor absorbs UV light and generates hydroxyl radicals.(figure2). Specifically, during UV illumination of TiO₂, conduction band electrons and valence band holes

*Corresponding Author: Jila talat mehrabad, Department of Chemistry, Faculty of science, Islamic Azad University, Bonab Branch, Bonab Iran. Email: Rahan.farham@gmail.com

are initially yielded (Eq. 1). Band electrons interact with surface adsorbed molecular oxygen to yield superoxide radical anions (Eq.2), while band holes interact with water to produce hydroxyl radical (Eq. 3).

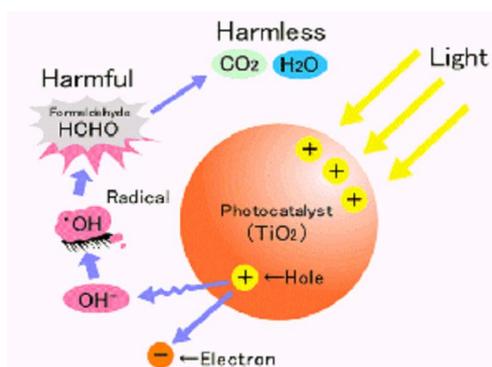


Figure2. TiO2 mechanism

Advanced oxidation processes (AOPs) are the methods in which $\text{OH}\cdot$ radicals are produced. $\text{OH}\cdot$ is a powerful oxidizing agent and completely degrades the most of organic pollutants. It is possible to use some metallic oxides and sulfides as catalysts for these processes[4-8]. The hydroxyl radical is an extremely strong, non-selective oxidant ($E^0 = +3.06 \text{ V}$) which leads to the partial or complete mineralization of several organic chemicals.



Electrons in the conduction band are also responsible for the production of hydroxyl radicals, species which have been indicated as the primary cause of organic matter mineralization (Eq. (8)) [10-12].



2. EXPERIMENTAL

2.1. Materials

Acid red 18, zinc oxide, potassium hydroxide, sulfuric acid, ethanol and hydrogen peroxide were of laboratory reagent grade and used without further purification.

2.2. light source and Photoreactor

For UV/ZnO process, irradiation was performed in a batch photoreactor system consists of a wooden chamber with aluminum foil cover, UV-C lamp (30 W, Philips), magnetic stirrer and a 500 ml beaker as reaction chamber.

2.3. Procedures

Proper volumes of AR18 stock solution were mixed with photocatalyst ZnO and were diluted to 100 ml. then 50 ml of the prepared suspension was transferred to a 500 ml pyrex reactor.

The suspension pH values were adjusted at desired level using dilute KOH and H_2SO_4 and then the pH values were measured with pH meter. After that, the lamp was switched on to initiate the reaction. Absorbance of this solutions with proper pH was determined at $\lambda = 500 \text{ nm}$. By this method conversion percent of AR18 can be obtained in different intervals.

The amount of dye adsorbed (Q_e) and efficiency η (%) of magnetic hollow spheres were calculated by the following equations:

$$Q_e = (C_o - C_e) \times (V/M)$$

$$\eta = ((C_o - C_e) / C_o) \times 100$$

where C_o and C_e are the initial and equilibrium concentrations of dye (mg L^{-1}), M is the mass of magnetic hollow spheres (g), and V is the volume of solution (L). Adsorption isotherms were investigated by Langmuir and Freundlich models and the reactions kinetics was performed by pseudo-second-order reaction kinetic equation.

3. RESULTS AND DISCUSSIONS

3.1. Effect of UV irradiation time and ZnO

The results are shown in figure 3 and it can be seen that in the absence of UV light or ZnO, the conversion fraction was near to zero. This shows that both of UV light and ZnO photocatalyst were necessary to efficiently remove the AR18 from solution.

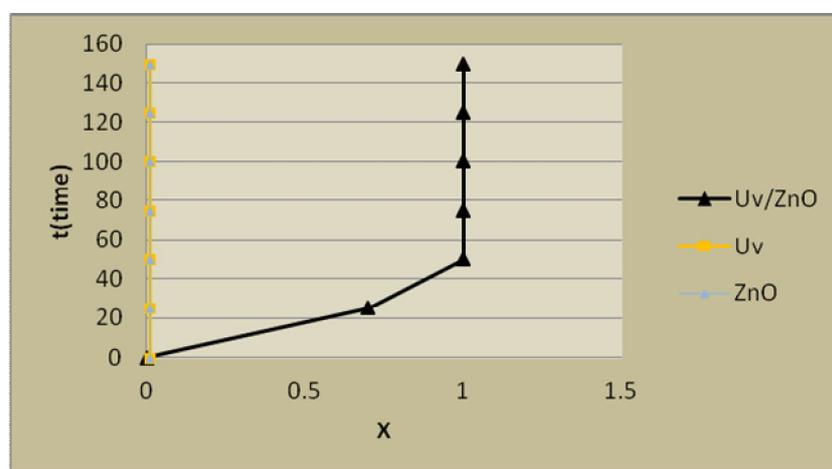


Figure 3. Effect of ZnO and UV irradiation

3.2. Effect of pH

The major factor affecting TiO_2/UV light process solution's pH. Fig. 4 shows the color removal efficiency of acid red 18 solution at 50 min irradiation time. It can be seen that the photocorrosion of ZnO is complete at pH lower than 5.

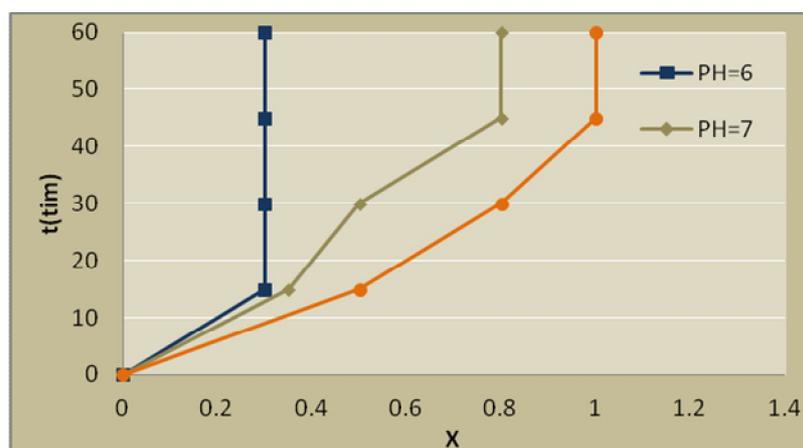


Figure4. Effect of pH

3.3. Effect of hydrogen peroxide

The degradation rate of AR18 increased with increasing H₂O₂ concentration but at high H₂O₂ concentrations, the produced OH• radicals react with each other and therefore, AR18 removal efficiency did not more increase (Figure5).

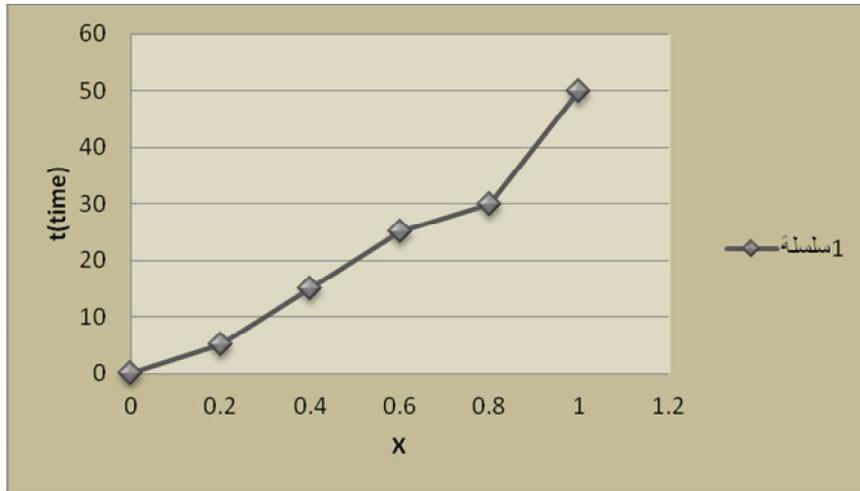


Figure5. Effect of H₂O₂

3.4. Effect of ZnO concentration on AR18 removal

The results of this research show that removal of AR18 dye has direct correlation with ZnO concentration. The best results of dye degradation were reported in concentration of 145 mg/L ZnO nano-particles. Rate of dye removal was decrease with increasing of color concentration.

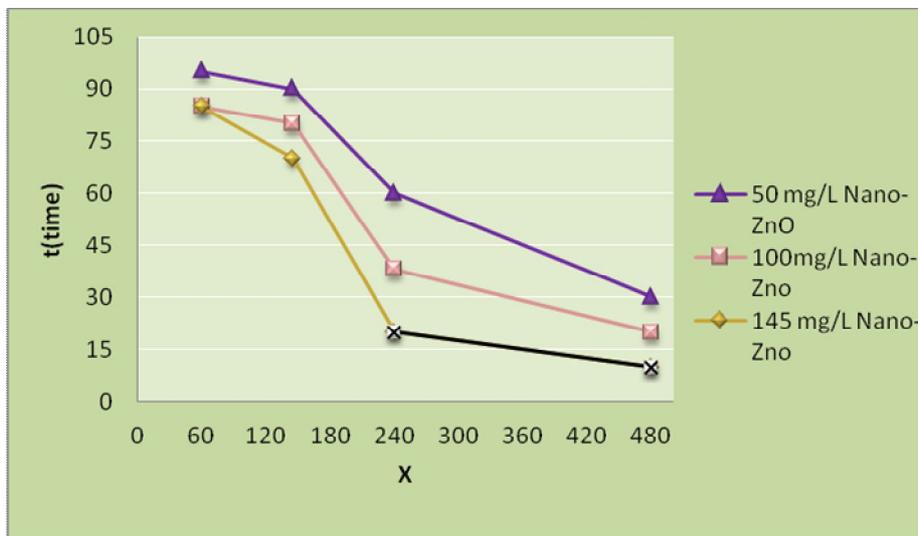


Figure6. Effect of ZnO concentration

4. Conclusion

In this research, the removal efficiencies of Acidic dyes (Acid Red18) that has the most application in the Iranian textile industries, by using of advance oxidation TiO₂/UV /ZnO were investigated. Titanium dioxide nanoparticles as a photocatalyst breakdown and remove a variety of environmental pollutants. TiO₂ not only removes the pollutants but also breaks them down into environmentally acceptable products. In UV/H₂O₂ process the absence

of each of UV irradiation or H₂O₂ decreased AR18 removal efficiency near to zero. Increasing H₂O₂ concentration increased dye removal to some extent but it was inhibited by ethanol. PH is a very important factor because it affects the electrostatic charge of the photocatalyst ions as well as the surface of the semiconductor particles. The results of this research show that removal of acid Red18 dye has direct correlation with UVA intensity.

REFERENCES

- [1] N. Daneshvar, D. Salari, A.R. Khataee, *J. Photochem. Photobiol. A*, 157 (2003) 111.
- [2] H. Lachheb, E. Puzenat, A. Houas, M. Ksibi, E. Elaoui, C. Guillard, *J. Appl. Catal. B* 39 (2002) 75.
- [3] N. Daneshvar, D.Salari,A.R.Khataee ,*J. Photochem. Photobiol A*162 (2004) 317-322.
- [4] N. Daneshvar,S.Aber,F.Hosseinzadeh,*J.Global Nest*,Vol 10,No 1(2008)16-23
- [5] P.R. Gogate , A.B. Pandit,*J. Environ. Res*, 8 (2004) 501-551.
- [6] A. Fujishima, T.N. Rao, D.A. Tryk, *J. Photochem. Photobiol. C, Photochem. Rev.* 1 (2001) .
- [7] J.C.Crittenden, T R.R.russell, D.W. Hand, K.J. Howe *J.second ed.*, Wiley, New Jersey,(2005).
- [8] A.S. Stasinakis, *J.Global Nest*,Vol 10,No 3(2008),376-385
- [9] N. Daneshvar, D. Salari, A.R. Khataee , *J. Photochem. Photobiol. A: Chem*, 162(2004) 317-322.
- [10] G. Marci, V. Augugliaro, M.J.L. Munoz, C. Martin, L. Palmisano, V. Rives, M. Schiavello, R.J.D. Tilley, *J. Phys. Chem. B* 105 (2001) 1033.
- [11] N. Daneshvar, D. Salary, M.A. Behnasuady, *Iran J. Chem. Chem. Eng.* 21 (2002) 55.
- [12] C. Galindo, P. Jacques, A. Kalt, *J. Photochem. Photobiol. A* 130(2000) 35.