DECOLOURIZATION OF DYE BY PHOTO-CATALYSIS PROCESS USING PAINTING GLASS WITH TiO_2 AND SUNLIGHT

Salam K. Al-Dawery and Maryam AL-Shehimi
Department of Chemical Engineering, University of Nizwa, Sultanate of Oman
Email: salam@unizwa.edu.om

Abstract. The aim of this study is to use TiO_2 painted on flat glass and sunlight as the source of UV light for the degradation of organic compounds on the outside building and houses and be used as self-cleaning agent. Advanced oxidation processes (AOPs) with UV irradiation and photo catalyst titanium dioxide (TiO_2) are gaining growing acceptance as an effective wastewater treatment method. The experimental results showed that considerable dye degradable has been achieved and that the non mobilized TiO_2 particles (painted on a wall of glass) have an effective performance on degradation of dye concentration. It was found that the major factor effecting degradation of dye is the intensity of UV light.

Keyword: Photo-catalytic Process; TiO_2; Tartrazine.

INTRODUCTION

A wide range of organic compounds is detected in industrial and municipal wastewater. Some of these compounds (both synthetic organic chemicals and naturally occurring substances) pose severe problems in biological treatment systems due to their resistance to biodegradation or/and toxic effects on microbial processes [1, 2]. As a result, the use of alternative treatment technologies, aiming to mineralize or transform refractory molecules into others which could be further biodegraded, is a matter of great concern. Among them, advanced oxidation processes (AOPs) have already been used for the treatment of wastewater containing recalcitrant organic compounds such as pesticides, surfactants colouring matters, pharmaceuticals and endocrine disrupting chemicals. Moreover, they have been successfully used as pre-treatment methods in order to reduce the concentrations of toxic organic compounds that inhibit biological wastewater treatment processes [3, 4]. Photo-catalysis is an advanced oxidation process in which the reaction is initiated by UV light illumination on a catalyst. It is an environmentally friendly technology in terms of material; the photo-catalyst, i.e. titanium dioxide (TiO_2) is safe to handle as it is not a toxic material and can be regenerated [4].

The aim of this study is to use TiO_2 painted on flat glass and sunlight as the source of UV light for the degradation of organic compounds in wastewater. This process can give an idea for using TiO_2 on the outside building and houses and be used as self-cleaning agent.

The photo-catalysis is one of the techniques, which are so called “advanced oxidation processes (AOPs)”. These processes can completely degrade the organic pollutants into harmless inorganic substances such as CO_2 and H_2O under moderate conditions. The AOPs are characterized by the production of OH• radicals which are extraordinarily reactive species (oxidation potential 2.8 V) and capable of mineralizing organic pollutants. They are also characterized by a little selectivity of attack, which is a useful attribute for an oxidant used in wastewater treatment. They attack most of the organic molecules with different rates; therefore, providing a valuable technique when multi contaminated wastewater, e.g. refinery wastewater is considered .The photo-catalysis has been tested on many different compounds including environmentally relevant organic compounds and in many different processes [5].

The Titanium Dioxide

There are three types of crystal structure in TiO2; anatase, Rutile and BrooKite types. The band gap value for anatase type is 3.2 e V, for rutile is 3.0 e V, and for the brookite is 2.96 e V. The necessary wavelength (λ) for TiO_2 is approximatly. 380 nm, which tells us that the light needed to activate TiO_2 is the ultraviolet light. Degussa P25 also can be worked under the sun light due to the UV light which is about 5% of solar energy reaching the earth [4]. The estimation of the wavelength can be carried out as shown below:

$$\lambda = \frac{hc}{E}$$

Where:

E: band gab for TiO_2 =3.2 eV = 3.2 x 1.6 x 10^{-19} J

h: Plank's constant = 6.63 x 10^{-34} J.s

C: light speed = 3.0 x 10^{8} m/s

λ = wavelength

$$\lambda = \frac{6.63x10^{-34}\ x3.0x10^{8}}{3.2x1.6x10^{-19}} = 380\ nm$$

METHODOLOGY

1. Material

In this project, the photo-catalysis that is considered to be used is TiO2 (P25, Degussa AG, Germany) with a surface area of 50 $m^2.g^{-1}$ and a primary particle size of 20 nm. Degussa P25, a commercially produced form of titanium dioxide and reference catalyst is composed of both phases: 80 % anatase and 20% rutile. For the organic pollutant, Tartrazine dye is used due to its wide application in food, non-food and drugs industries, the chemical structure of the Tartrazine dye is shown in Figure 1. Sunlightis also is considered as the source for the UV light.

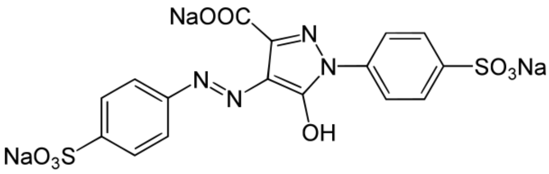

Figure 1. Tartrazine chemical structure

2. Experimental procedure

For exterior experiment, firstly, prepare the contaminated solution (water + dye) in a beaker, then, add a small amount of titanium dioxide powder to the solution as such 100 mg/l is achieved. Mixing the solution very well in order to dissolve the powder perfectly. Connect the vessel by tubes as a series with pump to the float type photoreactor as shown in Figures 2 and 3. After that, exposed the system to the sun light for a period of time. The degradation of toxic organic material percentage is measured by Vis-Spectrophotometer.

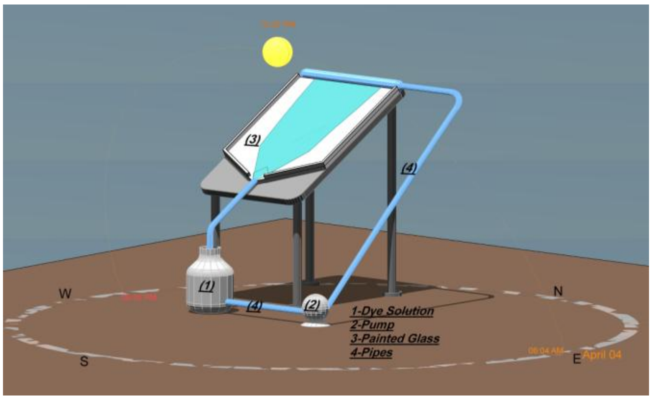

Figure 2. A schematic of experimental diagram

Figure 3. Experimental set up

RESULTS AND DISCUSSION

Firstly, a calibration curve was drawn for measuring concentration of dye based on standard prepared mixture and the equivalent wave absorption reading on the UV spectrophotometer as shown in Figure 4.

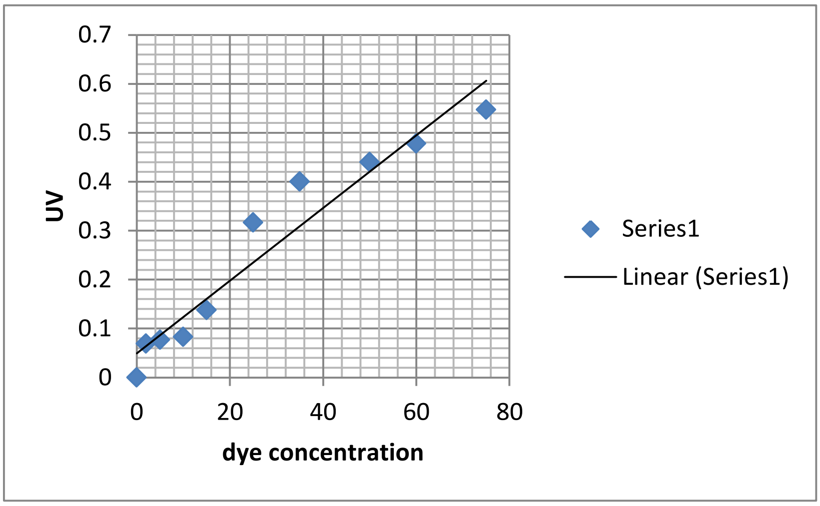

Figure 4 Calibration curve for finding concentration of dye in the solution

A series of experiments were carried out to find the influence of TiO_2 on dye solution at different concentrations; 25mg/l, 50 mg/l and 100 mg/l as shown in Figures 5, 6 and 7 which shows that the dye concentrations were decreasing with time. Results in Figure 5 and 6 show that the changing of flow rate (from 8.3 ml/s to 5.55 ml/s) that passing on the painted plate with TiO_2 does not have much effect on the degradation rate of the dye. These results showed clearly the effective of sunlight in the oxidation process. However, the effect of uv-sunlight has a very high impact, the less intensity of the light during cloudy day resulting lower rate of degradation of dye as shown in Figure 7.

However, longer time of degradation is may be due to the incomplete degradation of the reused solution. To overcome this problem, longer time may be given for completeness of the degradation process.

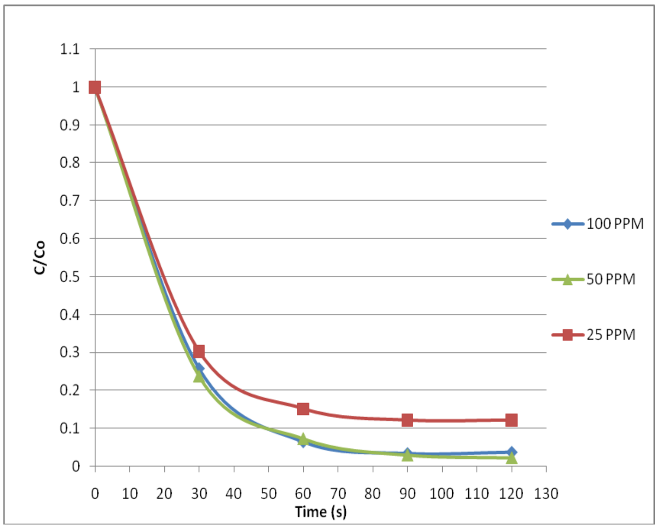

Figure 5. Degradation of Dye: 25, 50 and 100 PPM concentrations at high flow rate

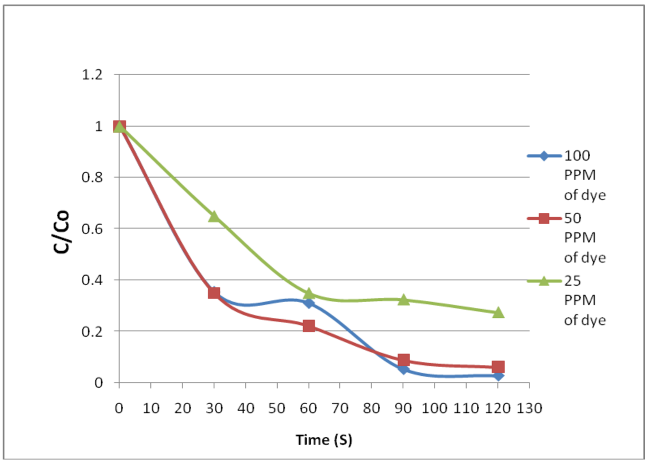

Figure 6. Degradation of Dye: 25, 50 and 100 PPM concentrations at low flow rate

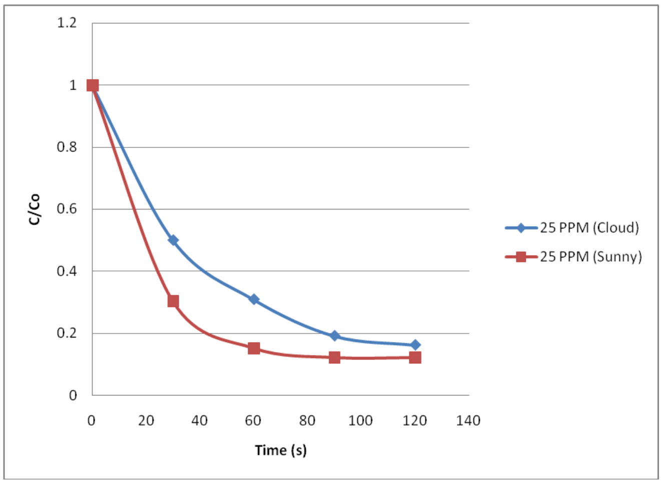

Figure 7. Degradation of Dye of 25 PPM at low and high light intensity

Solution temperature has been raised by 22 ^{o}C from 36 ^{o}C, at this range of temperature, there will be no much effect on the process of photo degradation, a very high temperature changes would have a significant effect on degradation due to the solution evaporation and reduction in O_2 concentration during the experiment. Such effect was not noticed. Also during experiments, the intensity of UV sunlight has been measured at different range of UV band at the site of the University of Nizwa as shown in Table 1.

Table 1 Range of UV during one day at the UoN site

UV band	At 10:50 am	At 11:50 am	At 3:40 pm (cloud)
254nm	0 nm	0 nm	0 nm
312nm	0.491 nm	0.677nm	0.027 nm
365nm	1.827 nm	2.2 nm	0.195 nm

CONCLUSION

This study showed the potentialities of photo-catalytic degradation of organic compounds such as Tartrazine in water purification. Out of different experimental runs employed, a significant enhancement of the photo-catalytic activity was observed using photo-catalyst irradiated under UV Sunlight. The painted TiO_2 showed a good ability as reusable material in the photo-catalytic process and in all the experimental run behaves as fresh material and the photo-catalytic process mechanism showed similar performances to that of fresh solution. The use TiO_2 painted on flat glass and sunlight as the source of UV light for the degradation of organic compounds shows a good ability of using TiO_2 on the outside building and houses and be used as self-cleaning agent.

REFERENCES

[1] http://www.mchnanosolutions.com/mechanism.html(2013)

[2] Mohammed Irfan, Wastewater Treatment in Textile, Tanneries and Electroplating Industries especially by Activated Sludge Method- A technical report, Journal of Pakistan Institute of Chemical Engineers, Vol. 37 (2009), 35-50.

[3] Abhilasha Dixit, A.K.Mungray and Mousumi Chakraborty, Photochemical Oxidation of Phenol and Chlorophenol by $UV/H_2O_2/TiO_2$ Process : A Kinetic Study, International Journal of Chemical Engineering and Applications, Vol. 1, No. 3, October (2010), 247-250.

[4] P. Stepnowski, E.M. Siedlecka, P. Behrend, B. Jastorff, Enhanced photodegradation of pollutants in petroleum refinery wastewater, Water Res. 36 (2002) 2167–2172.

[5] http://en.wikipedia.org/wiki/Titanium_dioxide(2013)

[6] Salam Kadhim Al-Dawery and Balqees AL-Abri, Photocatalytic Destruction Of Tartrazine Dye In Waste Water Using Tio2 And Sunlight, 3rd National Symposium on Engineering Final Year Projects, University of Nizwa, Oman, 2013.