PHOTOCATALYTIC DEGREDATION OF ACID ALIZARIN BLACK USING POWDER AND NANOPARTICLES OF TITANIUM DIOXIDE

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ABSTRACT

Photocatalytic degradation of acid alizarin black (AAB) dye (C.I. 21725) in aqueous solution was investigated using UV light in the presence of powder of titanium dioxide (P- TiO_2) and nanoparticles of titanium dioxide (N- TiO_2) as a catalyst. The operating conditions were catalyst dosage (10 and 20 mg/L) and initial concentration of AAB dye (10 and 20 mg/L). It was found that the increasing of catalyst concentration enhanced the dye decolourisation. Both catalysts exerted positive effects on the AAB removal whilst the initial concentration of AAB negatively affected its removal.

KEYWORDS: *Photocatalytic, AOPs, catalyst, wastewater, nanoparticles.*

INTRODUCTION

Many modern techniques of treatment have been used over the last few decades for treat and purify water. Ozonation and photolysis techniques, for example, have been used successfully to degrade and reduce a range of organic and biological pollutants (Rice and Hoff 1981; Rice and Browning 1981). However, stronger oxidant are produced (i.e. radicals) when these techniques are combined with some additives such as hydrogen peroxide and catalysts, and these processes together with additives are called Advanced Oxidation Processes (AOPs) (Glaze, Kang et al. 1987). AOPs are typically based on redox reactions as a result of gaining and losing electrons by radicals and organic molecules, respectively (Rice and Netzer 1983). Among AOPs, in recent years, heterogeneous photocatalysis methods have received a great attention in degrading or reducing organic pollutant (Al-Ekabi, Safarzadeh-Amiri et al. 1991).

It is estimated that, in textile industries, more than 10% of the dye is lost during the process of dyeing and discharged as effluent (Weber and Stickney 1993). Since the existence of small quantities of dyes (even bellow 1 part per million) is clearly visible, the discharge of those coloured water pollutants in the environment is a considerable non aesthetic pollution source. Through hydrolysis, oxidation or other chemical reactions taking place in the phase of wastewater, wastes of dyes can also produce dangerous by-products and eutrophication (Zollinger 1991; Tang, Zhang et al. 1997). Therefore, dye effluents decolourisation has received increasing attention. Using TiO_2 as a photocatalyst, among heterogeneous photocatalysis, appears as the most emerging destructive method for decolourisation of dye effluents (Ollis and Al-Ekabi 1993). By using irradiation and solar technology, different kinds of dyes have been successfully reduced or degraded in a batch scale (Neppolian, Sakthivel et al. 1998; Wang 2000; Zhu, Wang et al. 2000). This study outlines the results achieved for the degradation of acid alizarin black (AAB) in the presence of both powder TiO_2 (P-TiO_2) and nanoparticle of TiO_2 (N-TiO_2). Various operating parameters were studied in this research including initial concentration of AAB and catalyst dose.

METHODOLOGY

Materials

Acid alizarin black (AAB) was purchased from Hopkin and Williams LTD, UK and used as received. A stock solution of AAB (100mg/L) was prepared on a daily basis in distilled water and other concentrations (10 and 20 mg/L) were prepared by dilution the stock solution of AAB. The prepared stock solution was covered and kept in dark. Titanium dioxide (TiO_2), with particle size of 45 μm, was purchased from ALPHA CHEMIKA, India; and nanoparticles of TiO_2, with particle size of 21 nm, was purchased from Sigma-Aldrich, UK, and used as received without further treatment. UV lamp with 254 nm (12 watt) was purchased from SEMTEC, China.

Experimental procedures

A closed semi-batch reactor, as shown in **Fig. 1**, was used in this study. A 500 mL of the AAB solution at a specific concentration was charged into the reactor, this solution prepared from the stock solution by dilution. The volume of the reactor was 600 mL. It is made from PYREX glass and fitted with a sample port. The reactor was equipped with a plunging tube in which a SEMTEC 12 watt lamp was placed horizontally. A glass syringe with 5 mL volume was used, at a specific schedule, to collect samples. A centrifuge was used for 10 min to separate titanium dioxide from the solution before analysis. Visible spectrophotometer (Jenway, 6700) was used to analyse the collected samples.

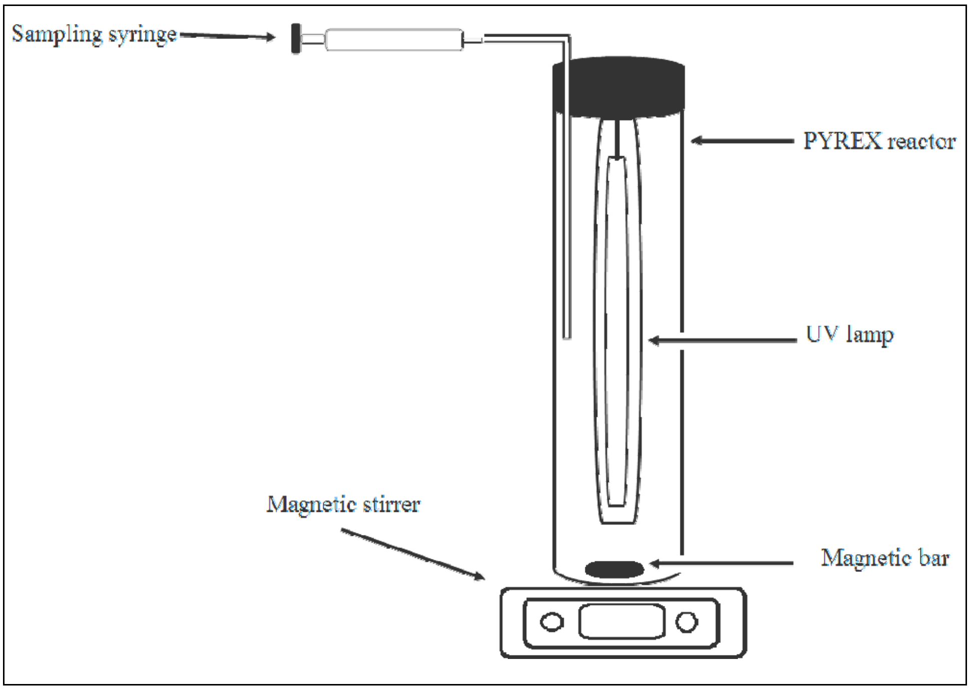

Fig. (1) *Photocatalytic reactor*

RESULTS AND DISCUSSION

Effect of initial TiO_2 concentration

The effect of TiO_2 concentration on AAB decolourisation was studied and the results are shown in **Fig.2**. The figure shows the decolourisation of AAB solution in the presence of both P-TiO_2 and N-TiO_2. The other experiment conditions were kept constant (AAB concentration was set to 10 mg/L, pH 6.84, and room temperature 22^{o}C). The catalyst concentrations used were 10 and 20 mg/L for both catalysts. **Fig. 2** also shows how the increasing catalyst concentration increases the removal efficiency. After 60 min reaction time, the decolourisation rate of AAB increased when concentration of both catalysts increased. It was found that the rate of decolourisation enhanced when N-TiO_2 was used instead of P-TiO_2.

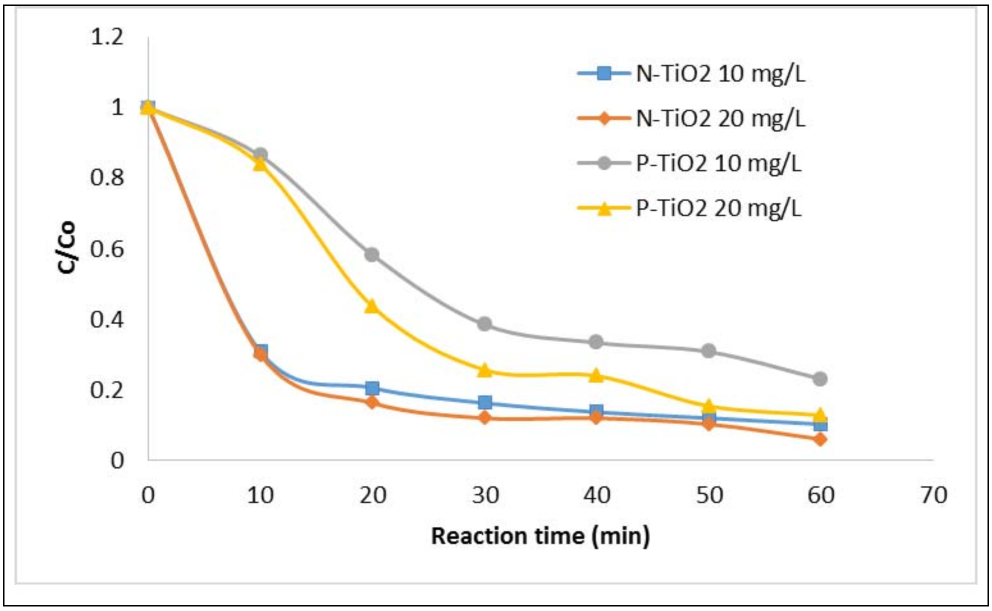

Fig. (2) *AAB removal by using different concentrations of catalyst at 60 min ([AAB]$_o$ = 10 mg/L, Temperature= 22 ^{o}C, Volume = 500 mL, pH= 6.84)*

The removal percentage of AAB increased and reached 77 % and 87 % after using 10 and 20 mg/L of P-TiO_2, respectively (see **Fig. 3**). However, the removal percentage enhanced and reached 90 % and 94 % when 10 and 20 mg/L of N-TiO_2 used, respectively. The removal efficiency of AAB was recorded the lowest removal percentage when 10 mg/L of P-TiO_2 used.

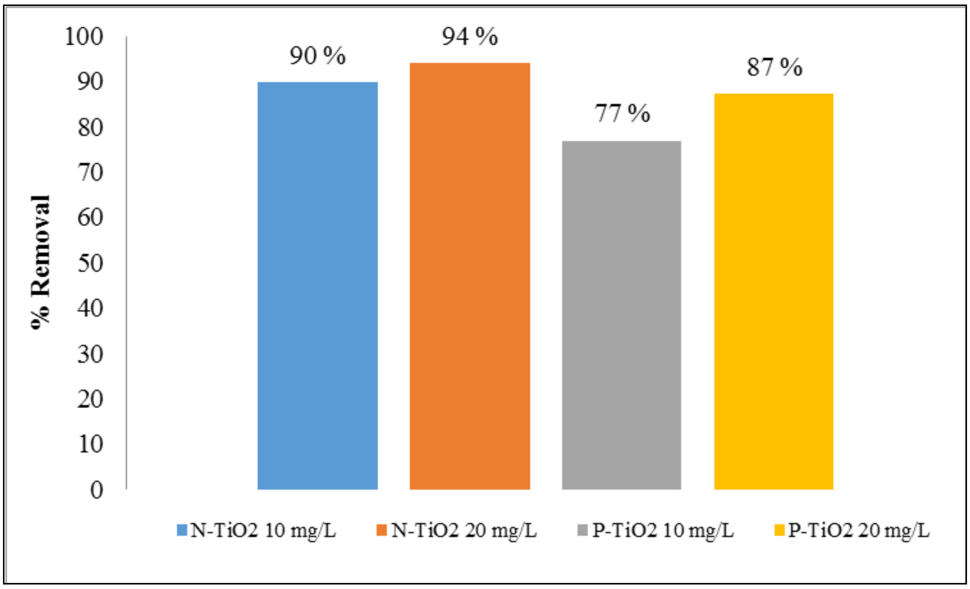

Fig. (3) *AAB removal percentage at various concentrations of catalyst at 60 min ([AAB$_o$ = 10 mg/L, Temperature= 22 ^{o}C, Volume = 500 mL, pH= 6.84)*

Effect of initial AAB concentration

The effect of initial concentration of AAB on the decolourisation rate of AAB using UV light in the presence of P-TiO_2 and N-TiO_2 was studied. The results show that increasing the initial concentration of AAB reduced the decolourisation rate (see **Fig. 4**). The decolourisation percentage of AAB in the presence of P-TiO_2 at 60 min reaction time decreased from 77 % to 74 % when AAB concentration increased from 10 to 20 mg/L, respectively (see **Fig. 5**). However, the decolourisation percentage in the presence of N-TiO_2 decreased from 90 % to 87 %.

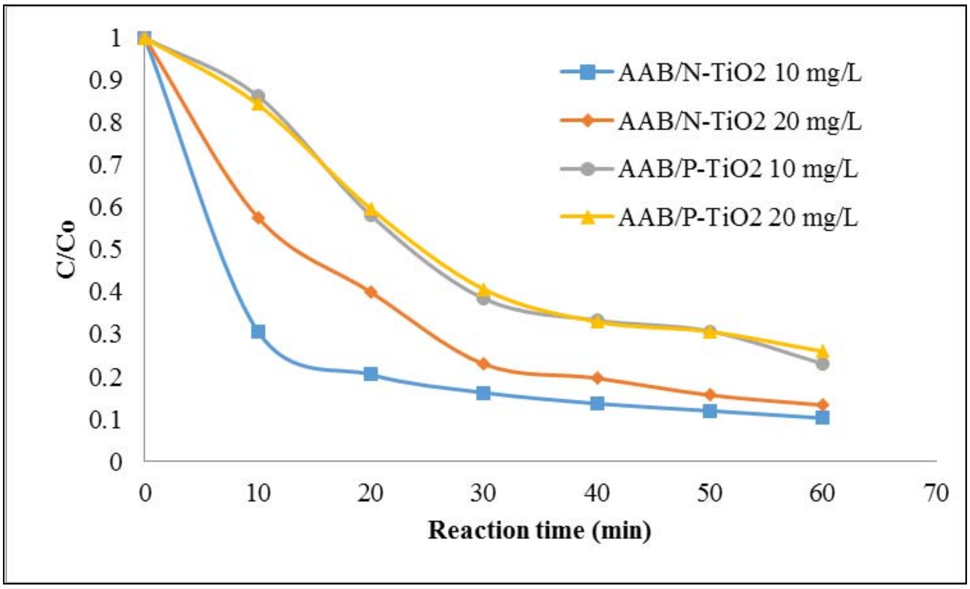

Fig. (4) *Effect of initial AAB concentration on solution decolourisation at 60 min (Temperature= 22 ^{o}C, Volume = 500 mL, pH= 6.84)*

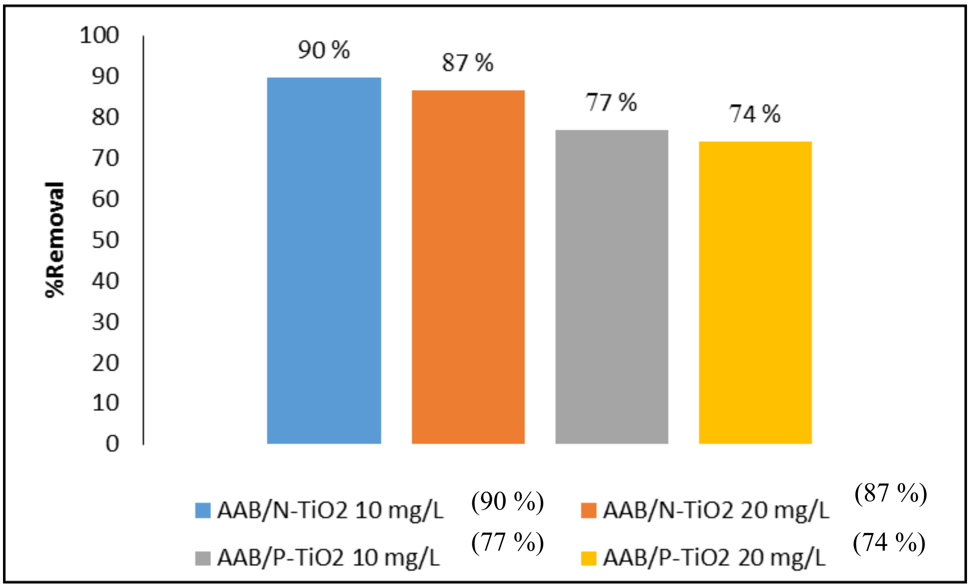

Fig. (5) *AAB removal percentage at various concentrations of AAB at 60 min (Temperature= 22 ^{o}C, Volume = 500 mL, pH= 6.84)*

CONCLUSIONS

Photocatalytic degradation of acid alizarin black (AAB) in the presence of powder of TiO_2 (P-TiO_2) and nanoparticles of TiO_2 (N-TiO_2), under different operating conditions, was studied in this research. The operating conditions were catalyst dosage and initial concentration of AAB. The most effective improvements on the degradation of AAB were recorded when N-TiO_2 was used. It was found that the increasing of catalyst concentration enhance the reaction rate of AAB decolourisation. It is also found that the removal percentage of AAB reached the maximum value when 10 mg/L of AAB used instead 20 mg/L.

REFERENCES

- Al-Ekabi, H., A. Safarzadeh-Amiri, et al. (1991). "Advanced technology for water purification by heterogeneous photocatalysis." International Journal of Environment and Pollution 1(1-2): 125-136.
- Glaze, W. H., J. W. Kang, et al. (1987). "The Chemistry of Water Treatment Processes Involving Ozone, Hydrogen Peroxide and Ultraviolet Radiat." International Ozone Association 9: 335-352.
- Neppolian, B., S. Sakthivel, et al. (1998). Photocatalytic degradation of textile dye commonly used in cotton fabrics. Studies in Surface Science and Catalysis. T. S. R. P. Rao and G. M. Dhar, Elsevier. Volume 113: 329-335.
- Ollis, D. F. and H. Al-Ekabi (1993). Photocatalytic purification and treatment of water and air: proceedings of the 1st International Conference on TiO2 Photocatalytic Purification and Treatment of Water and Air, London, Ontario, Canada, 8-13 November, 1992, Elsevier.
- Rice, E. W. and J. C. Hoff (1981). "Inactivation of Giardia lamblia cysts by ultraviolet irradiation." Appl Environ Microbiol 42(3): 546-547.
- Rice, R. G. and M. E. Browning (1981). Ozone treatment of industrial wastewater. Park Ridge, N.J., Noyes Data Corp.
-Rice, R. G. and A. Netzer (1983). "Handbook of Ozone Technology and Applications, Vol 1, Rice,Rg, Netzer,A." Journal American Water Works Association 75(5): 64-64.
- Tang, W. Z., Z. Zhang, et al. (1997). "TiO2/UV photodegradation of azo dyes in aqueous solutions." Environmental Technology 18(1): 1-12.
- Wang, Y. (2000). "Solar photocatalytic degradation of eight commercial dyes in TiO2 suspension." Water Research 34(3): 990-994.
- Weber, E. J. and V. C. Stickney (1993). "Hydrolysis kinetics of Reactive Blue 19-Vinyl Sulfone." Water Research 27(1): 63-67.
- Zhu, C., L. Wang, et al. (2000). "Photocatalytic degradation of AZO dyes by supported TiO2 + UV in aqueous solution." Chemosphere 41(3): 303-309.
- Zollinger, H. (1991). Color chemistry: syntheses, properties, and applications of organic dyes and pigments, VCH.

تێکچوونا بویاغا ترشێ ئەلیزارینێ رەش برێکا هاندەرێ روناهیێ ب کارئینانا پاودەر وگەردیلێن نانویی یێن دوانا ئوکسیدێ تیتانیوم

پوخته:

دڤێ ڤەکولینێدا تێکچوونا بویاغا ترشێ ئەلیزارینێ رەش (AAB, C.I. 21725) برێکا هاندەرێ روناهیێ هاته کرن دناڤ ئاوێتەکێ ئاڤی دا بکارئینانا تیشکا سەر بنەفشیدا وب هەبونا پاودەرێ دوانا ئوکسیدێ تیتانیوم ($P-TiO_2$) وگەردیلێن نانویی یێن دوانا ئوکسیدێ تیتانیوم ($N-TiO_2$) وەك كاریگەرەكێ هاندەر. باردوخێن كارى يێن ڤێ ڤەكولينێ پێك دهاتن (١٠، ٢٠ ملغم/ لتر) ژپەیتێ كاريگەرى دگەل پەیتێ سەرەتايى ب (١٠، ٢٠ ملغم/ لتر) یێ بویاغا AAB. هاتە دیتن ژڤێ ڤەکولینێ ب زێدەكرنا پەیتێ هاندەرى هاريكاريێ دكەت لسەر ژێبرنا رەنگێ بویاغا AAB. هەردوك هاندەران هندەك ئەنجامێن پوزەتیڤانە دان لسەر ژێبرنا بویاغا AAB لێ ب بكارئینانا پەیتێ سەرەتايى یێ AAB كارتێكرنەكا نێگێتیڤانە كر لسەر ژێبرنا ڤێ بویاغێ.

تدهور التحفيز الضوئي لصبغة حامض أليزارين الأسود بإستخدام المسحوق والجزيئات النانوية لثاني أوكسيد التيتانيوم

الخلاصة

تم دراسة تدهور التحفيز الضوئي لصبغة حامض أليزارين الأسود (AAB, C.I. 21725) في المحلول المائي بإستخدام الأشعة فوق البنفسجية وبوجود مسحوق ثاني أوكسيد التيتانيوم ($P-TiO_2$) والجزيئات النانوية لثاني أوكسيد التيتانيوم ($N-TiO_2$) كعوامل محفزة. وكانت ظروف العمل لهذه الدراسة هي (١٠، ٢٠ ملغم/ لتر) لجرعة المحفز والتركيز الأولي (١٠، ٢٠ ملغم/ لتر) لصبغ ال AAB. وقد وجد في هذه الدراسة أن زيادة تركيز المحفز يعزز من إزالة اللون لصبغةAAB . كلا المحفزين أعطت نتائج إيجابية في إزالة صبغة ال AAB في حين أن التركيز الأولي ل AAB تأثرت سلبياً في إزالة هذه الصبغة.