



[Science Archives \(ISSN:2582-6697\)](http://www.sciencearchives.org)

Journal homepage: www.sciencearchives.org



<http://dx.doi.org/10.47587/SA.2022.3203>




Research Article

Sonophotocatalytic treatment of thiazine (azure a) dye from wastewater using TiO₂ film

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Received: May 1, 2022/ Revised: May 19, 2022 / Accepted: June 2, 2022

Abstract

This research is including the efficiency of four methods of advanced oxidation processes and compares them for decolonizing the textile dye Azure A in an aqueous solution. These methods are TiO₂ only, ultrasound with titanium dioxide (TiO₂ +US) and titanium dioxide ultraviolet (TiO₂ + UV), and titanium dioxide with ultraviolet with ultrasound (TiO₂ +UV +US). The aim is to determine the best method of treatment for the mineralization of color. All the experiments have been done by using sonophotocatalytic experimental setup. The study includes the investigating effects of dye concentration, temperature, and pH. Complete degradation has been achieved in a somewhat short time of 60 min. The maximum removal of color was found in higher pH and temperature where at T=308K the removal percentage is 40%, 55%, 60%, and 99% and at pH=8 are 30%, 55.5%, 66%, and 98.5% by four methods consecution shown the removal rate that increases with decreases initial dye concentration, and also that the ratio of removal increases with the rise of temperature, which decreases activated energy of the reaction. As far as pH is concerned it appears that the ratio of removal decreased in an acidic medium. The decolonization reaction was found to follow first-order kinetics concerning the dye concentration.

Keywords TiO₂, Thiazine dyes, Azure A, Oxidation processes, Decolonization

Introduction

Thiazine dyes are one of the cationic dyes which contain a group of base main that acquires a proton under acidic conditions by the dye medium (Hussain et al., 2011; Orhan et al., 2004). The adsorption study for these dyes /is important for different physic-chemical operations and the understanding of phenomena such as explanation and de-pollution of industrial liquid wastes (Al-Rufaie et al., 2016). Adsorption of different kinds of dyes on the activated carbon and by using several adsorbents have been studied by using the experiment, that we found the modified charcoal was an active Azure C derivatives adsorbent, the rates of adsorption kinetic were calculated and cause for the choose the proper distinctive expressions average of possible mechanisms. So, the analysis kinetic of ad-sorption for the done editing charcoal may be of

a high value for the practice of the application of thiazine dyes elimination from the wastewater solution (Crini, 2016). Photocatalysis is generally referred to as the acceleration of a photoreaction by the presence of a semiconductor catalyst such as titanium dioxide (TiO₂) or zinc oxide (ZnO) (Nadagouda et al., 2017). Photocatalytic process, one of the Advanced Oxidation Processes, sounds to be a promising technology suitably fit for the remediation of organic pollutants under ambient conditions at minimal costs (Kargar et al., 2013). The use of natural solar UV energy (sunlight), instead of the artificial UV lamp, may help greatly in reducing the cost of photocatalytic oxidation with some alternative technologies. The availability of solar UV-irradiation in a specific geographical area, like Algeria, represents a major factor in determining the cost of a solar-based system (Sarma and Shinde, 2012). The wastewater from the dye manufacturing industry causes a serious impact on natural

water bodies and land in the surrounding area (Na et al., 2019; Bizania et al., 2006). Dye wastewater contains high organic loading, due to the high organic load, and toxicity, biological processes cannot be used, since no COD removal is achieved biologically (Doosti et al., 2012; Rahmani et al., 2012). Thus, a biological treatment is not feasible. In these cases, chemical pretreatment can adequately reduce the COD before biological treatment. Sonication has been widely known to induce radical reactions (Isha et al., 2012; Kidak and Dogan, 2012). This useful property has found its applications in sonolysis of water, sonolytic degradation of aqueous organic pollutants, and sonochemical synthesis of chemicals. The underlying phenomena include cavitation, microstreaming, and localized supercritical conditions. These phenomena lead to sonolytic splitting of water as well as pyrolysis of a vaporized molecule (Sharma et al., 2016; Salehi et al., 2016; Kargar et al., 2013).

Experimental parts

Materials and Instruments

All chemicals were of the highest purity from commercial suppliers such as B.D.H. and Aldrich. All chemicals are used Degradation of Thiazine Dyes Azure A by Sonolysis, Sonophotolysis, and Sonocatalysis The present research focuses on the application of advanced oxidation processes as Titanium dioxide (TiO₂), Titanium dioxide+ultrasound (TiO₂+US), Titanium dioxide and ultraviolet (TiO₂+UV) and sonophotocatalysis (TiO₂+US+UV) for the degradation of thiazine dyes (Azure A) in aqueous solution. In this study, the concentration, temperature, and pH. Complete degradation was achieved in a relatively short time at 60 min irradiation. Faster decolorization was achieved at high pH and temperature. The degradation with sonophotocatalysis (TiO₂+US+UV) was the fastest. The activation energy for both Azure dyes studied was decreased with temperature increase between 288-308 K. The decolourization of the dyes followed first-order kinetics. Also, both techniques sonophotocatalysis (TiO₂+US+UV) and photo-oxidation (TiO₂+UV) were applied in optimum conditions to investigate the best removal of dyes. The results show that the best method for complete degradation of dyes at short time 10 min irradiation is sonophotocatalysis. Sonoreactor (Powersonic Lab Tech model LUC-410), this model built-in microprocessor with thermometer with timekeeper between 0-99 min, with performed stainless steel baskets, capacity 10 L, temperature range (ambient to 50° C), frequency 40 kHz, power 500 W. Put the dye solution within the bath of ultrasound and then treated with it first without other factors and then treats solution with ultrasound and ultraviolet rays that are put on the solution from the top and then treated solution with ultrasound and TiO₂ shown in Fig. 1 Electronic spectra were recorded on UV-visible spectrophotometer Shimadzu model 1650 pc using 1 cm glass cell. pH measurements were carried out using Philips pw 9421 pH meter (pH ± 0.001). Titanium generator the TiO₂ was dried (Marte, MB 150/6) at 100 °C for 1 h until the formation of a xerogel and heat-treated in a muffle furnace (Jung, 9613) at 2

°C min⁻¹ and a plateau of 2 h at 400 °C. The device for UV irradiation was a low-pressure mercury lamp Bol and Philips, G6 T5, 4, 6, 10, 12 Watt. Fig. 2 shows the structural formula of Azures A dye that is used as a model of organic pollutants.

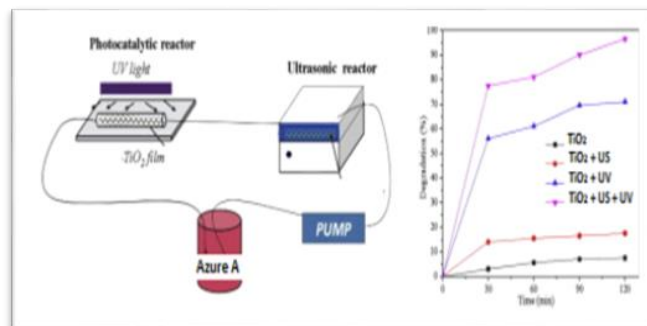


Fig. 1 Schematic of sonophotocatalytic experimental setup

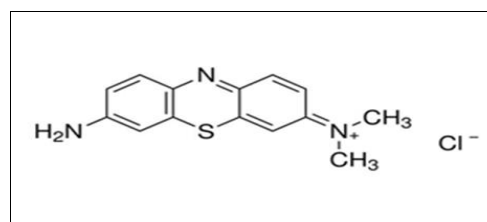


Fig. 2 Structural formula of Azure A dye

Preparation of dye solution

Preparation of dye solution: The effect of different factors on the rate of removal was investigated by preparing different solutions of dyes and studying each factor's aloneness. All experiments were conducted for a short time of 60 min. Switch on the ultra-sound generator for 10 min before the start of all experiments. irradiation and then irradiating the dye solution for a period of 60 min, then the absorbance was measured at $\lambda_{max} = 632$ nm for azure A Fig. 3 shows the spectrum of dyes, and Fig. 4 shows the calibration curve for Azure A dye.

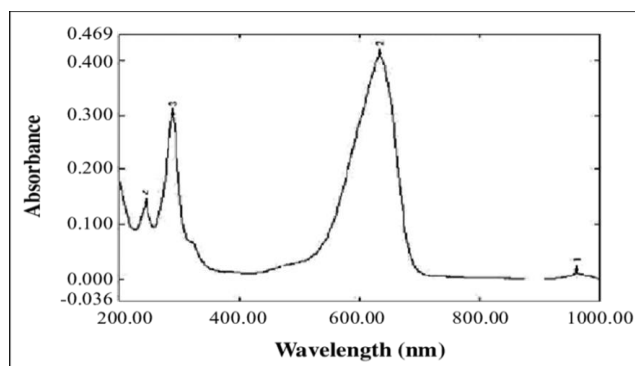


Fig. 3 UV-Visible spectrum of aqueous solution of Azure

A (1 x 10⁻⁵ M, T = 298 K)

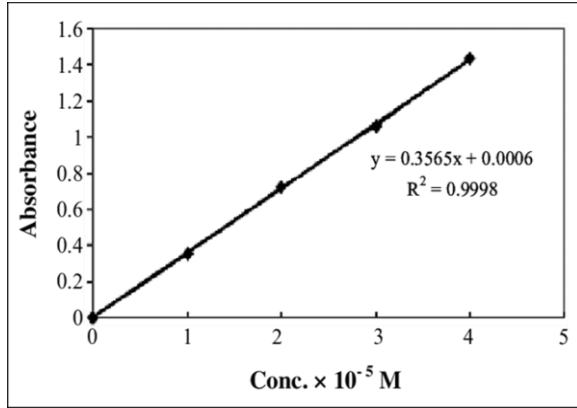


Fig. 4 Calibration curve for azure A at T = 298 K

irradiation decreased with the initial concentration increase. TiO₂+US+UV is the best efficient treatment than other methods.

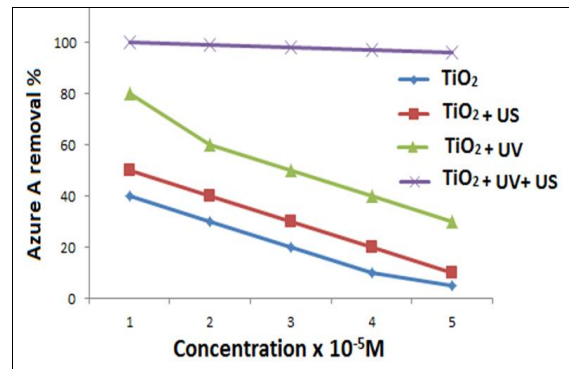


Fig. 5 Removal of Azure B and C dyes at different initial concentration at 298 K, pH 6, 40 kHz, Io = 19.30 mW/cm², 0.3 g/l

Results and discussion

Effect of concentration: The initial concentration of pollutants is important from an application viewpoint. Hence the efficiency of different treatment processes (TiO₂, TiO₂+US, TiO₂+UV, TiO₂+US+UV) has been evaluated through the characterization of the initial and treated Azure A aqueous solution Fig. 5 It is evident from the figures that the different initial Azure A dye concentrations give different removal ratios. The removal ratio decreased with increasing initial concentrations of dyes by four methods because the

According to kinetic studies, the removal rate of the dye is first-order reaction attribution to the dye concentration so the eqn. 1 can be used in the following from, where can be linked values of rate constant 'k' with different dye concentration 'c' and determine reaction order 'n' as described by equation 1 and Fig. 6.

$$\log R = \log k + n \log c \quad \dots\dots(1)$$

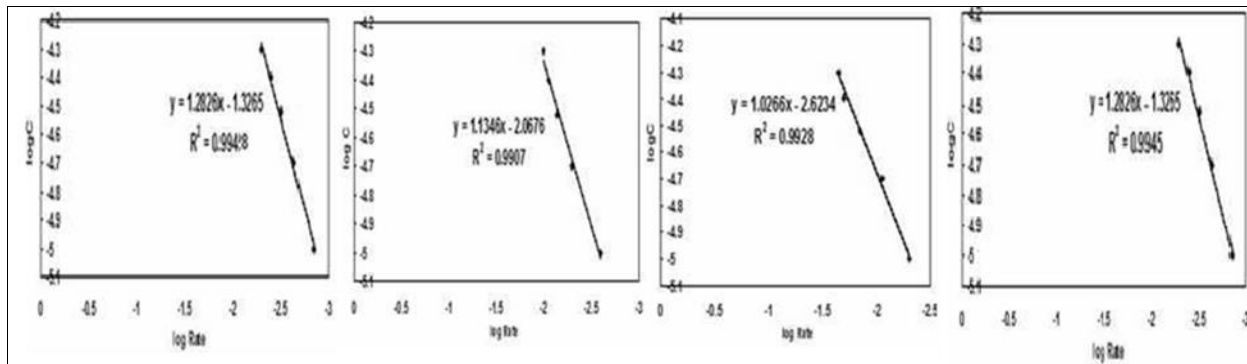


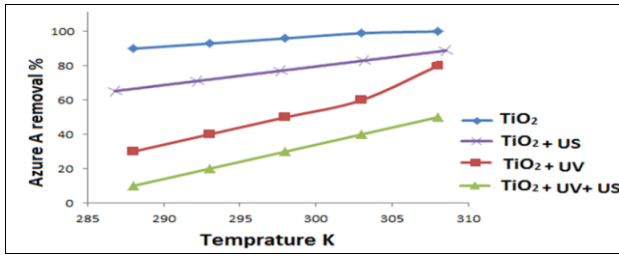
Fig. 6 Relationship between log R, log C for Azure B at 298 K, pH 6, 40 kHz, Io = 19.30 mW/cm², 0.025 g/min at different methods

Effect of Temperature

Throughout experiments it is found that the effect of temperature on the rate of removal is important as the rate of reaction increases gradually with temperature Fig. 7. Arrhenius equation was used to clarify the relationship between rate consistency and its temperature:

$$\ln k = \ln A - Ea/RT \quad \dots\dots\dots(2)$$

where,
k is rate constant,
A is frequency factor,
R is gas constant,
T is temperature.



Effect of initial pH: Effect of initial pH: This study includes the effect of different values of pH function limited between 2-8 on Azure A dyes solution, are found that the maximum rate of disintegration of the dyes solution when the value of pH = 8, with the increase of initial pH, the rate of reaction increases so that rises efficiency for color removal in four methods used Fig. 9

Fig. 7 Removal of Azure B and C dyes at different temperatures and methods at pH 6, 40 kHz, I_o = 19.30 mW/cm², 0.3 g/l

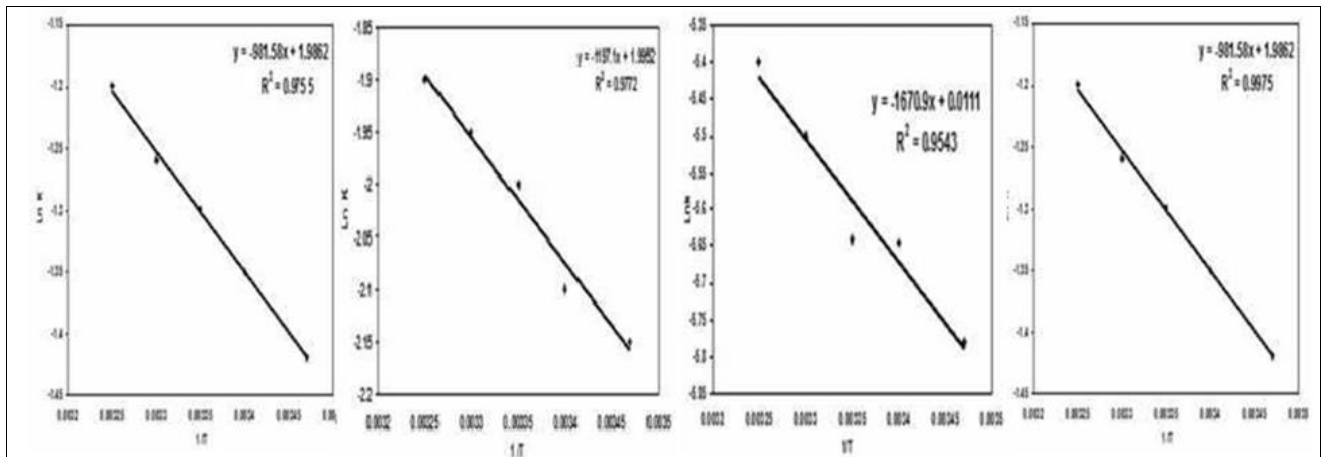


Fig. 8 Arrhenius eq. Azure B at different methods at pH 6, 40 kHz, I_o = 19.30 mW/cm², 0.3 g/l

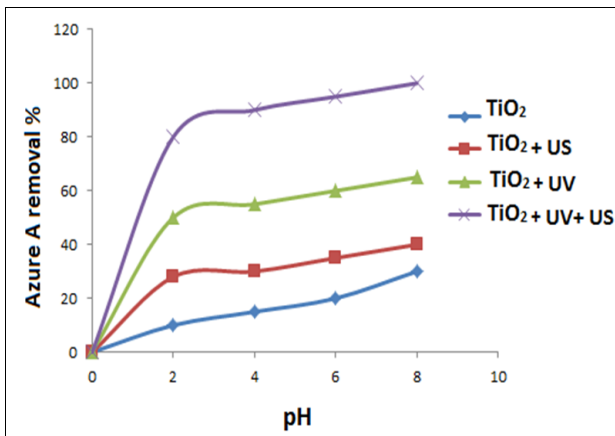


Fig. 9 Removal of Azure B and C at different pH at 298 K, 40 kHz, I_o = 19.30 mW/cm², 0.3 g/l

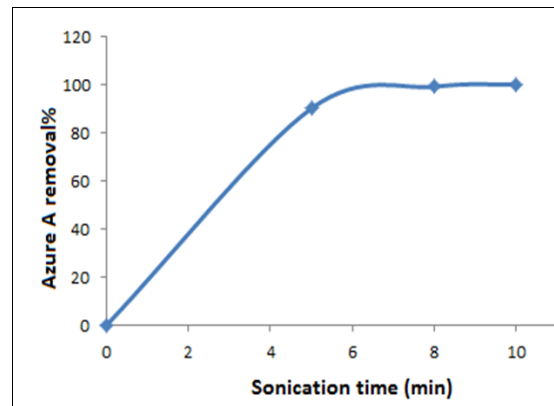


Fig. 10 Degradation of Azure B and C dyes at TiO₂+US+UV at pH 8, 308 K, 1 × 10⁻⁵ M, 0.3 g/l, 19.30 mW/cm²

Effect of combined US/UV/O₃ in optimum conditions: This includes the combination effect of ultrasound, ultraviolet and ozone (TiO₂+US+UV) on the rate of removal of dyes. The results showed that the rate of removal of dyes solution reach to summit at short time 10 min irradiation, comparison with each method alone. This effect is showed in Fig. 10

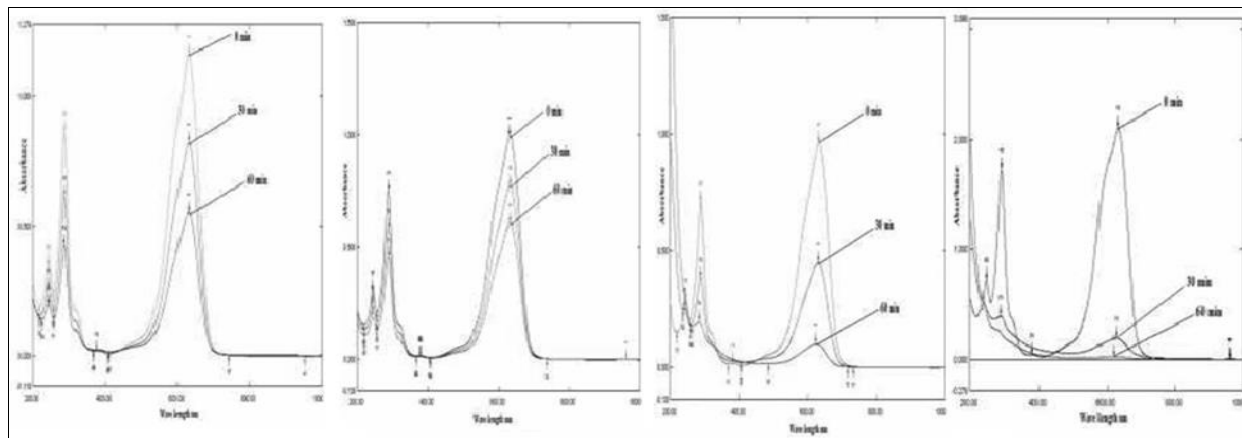


Fig. 11 UV-visible absorption of Azure A dye under effect four methods (A) TiO₂ only, (B) TiO₂+US , (C) (D) TiO₂+UV, (E) TiO₂+US+UV

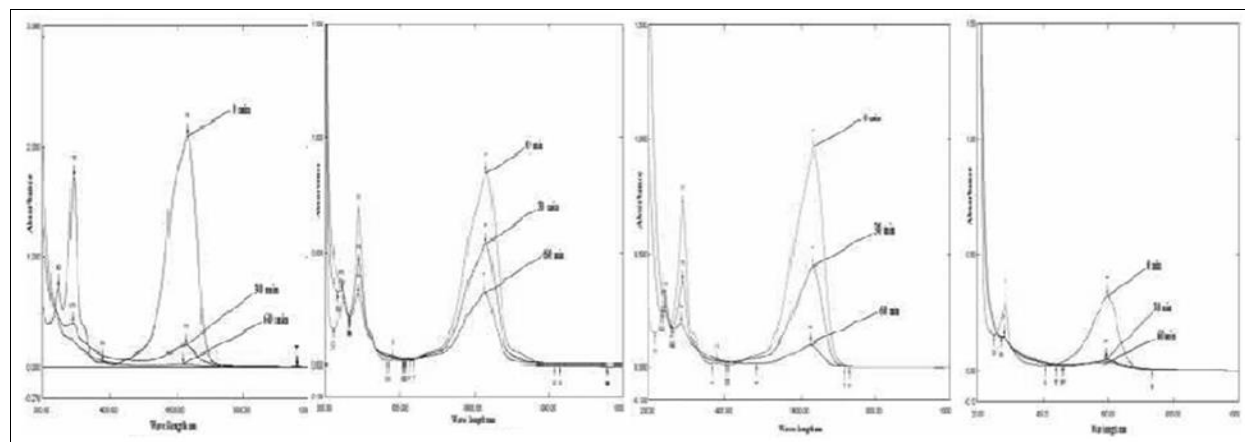


Fig. 12 UV-visible of Azure A dye under effect TiO₂+ US + UV at three different pH (A) pH 2, (B) pH 4, (C) pH 8

Conflict of Interest

The author hereby declares no conflict of interest.

Funding support

The author declares that they have no funding support for this study

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How to cite this article

Hamzah, A. T. (2022). Sonophotocatalytic treatment of thiazine (azure A) dye from wastewater Using TiO₂ film. *Science Archives* Vol. 3 (2), 98--103. <http://dx.doi.org/10.47587/SA.2022.3203>

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