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Photocatalytic Degradation of Amaranth Dye in Aqueous Solution Using Sol-gel Coated Cotton Fabric

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Abstract— **Immobilization of nanosized titanium dioxide on cotton fabric enhances the dye degradation efficiency of the photocatalyst due to dual effect of adsorption and photodegradation. The present study involves the process of immobilizatrion of titania particles on cotton fabric to overcome the drawbacks encountered with the powdered suspensions. The solgel coated cotton fabric was used to degrade the amaranth dye in aqueous solution in order to evaluate the photocatalytic performance. The prepared fabric showed enhanced dye degradation capabilities.**

***Index Terms*— Adsorption, amaranth dye, photocatalysis, solgel method, titanium dioxide.**

I. INTRODUCTION

Industrial textile dyes are present in wastewaters at different concentrations. Dye pollutants in wastewaters are the principal source of environmental aqueous contamination. They need to be removed from wastewaters by different methods. Photocatalysis has been successfully used to oxidize many organic pollutants and particularly to decolorize dyes. Among the new oxidation methods or "advanced oxidation processes" (AOPs), heterogeneous photocatalysis appears as an emerging destructive technology leading to the total mineralization of many organic pollutants. Some organic pollutants have been shown to be degraded and ultimately mineralized completely under UV irradiation on nanosized titania catalysts. Catalytic activity of titanium dioxide is based on the electron/hole pair formed upon photo excitation. A great deal of research has been conducted recently to optimize the performance of the TiO_2 photocatalysts with high surface area.

The use of slurries in wastewater treatment has some disadvantages: the separation of fine particles is slow and penetration of light is limited. These problems can be minimized by supporting TiO_2 on various materials. Many techniques have been developed to obtain advanced material based on TiO_2. Nanostructured materials are preferred over dense structures, because of their larger active surface. The production of nanostructured films is nowadays an established method and TiO_2 nanoparticles and mesoporous films are among the materials routinely produced through the solgel chemistry processing. It is very important to prepare TiO_2 films that are capable of harvesting incident light to a great extent, and at the same time films with a high surface area and porosity to increase the rate of reaction between photogenrated species and the pollutants.

The combination of adsorption and photodegradation process has been proposed by many researchers after realizing the noble potentials in both processes. It was proven that adsorption works well with photodegradation using TiO_2 in removing various pollutants. The dual effect was capable in increasing the efficiency or performance of the whole removal system.

The present study highlights the immobilization of solgel produced titanium dioxide on the cotton fabric for removal of amaranth dye in aqueous solution. The cotton fabric acts as adsorbent in adsorbing the dye molecule while TiO_2 nano-particles photodegrade the dye leading to increase in dye removal efficiency.

II. MATERIALS AND METHODS

A. Materials

Titanium (IV) isopropoxide (TIPO) was obtained from Acros, USA and Cetyltrimethyl-ammonium bromide (CTAB) AR was purchased from HiMedia Laboratories Pvt. Ltd, Mumbai. Amaranth ($C_{20}H_{11}N_2O_{10}S_3Na_3$) dye powder, Nitric Acid (HNO_3) LR and Ethyl alcohol (C_2H_5OH) AR were obtained from s d Fine-Chem Ltd, Mumbai.

B. Preparation of solgel coated cotton fabric

The precursor solution was prepared by mixing 10 ml titanium isopropoxide [$Ti(OC_3H_7)_4$] and 24 ml of ethanol followed by stirring for 0.5 hour. The hydrolysis catalyst solution was prepared by mixing 2ml of HNO_3 in 500 ml of double distilled water. The Cetyltrimethyl-ammonium bromide ($C_{19}H_{42}BrN$) solution was prepared by adding 5 gm of CTAB in 20 ml of distilled water. The gel preparation process started when the precursor solution and catalyst solution were mixed together and vigorously stirred for 0.5 hour. 6 ml of CTAB solution was added to the above mixture followed by stirring for 0.5 hour. CTAB to TIPO molar ratio was kept as 1:8. Hydrolysis of TIPO offered a turbid solution which was heated up to 60-70 °C for almost 24 hours until the solution reduced to 100 ml. The resultant suspension was white blue and opaque with high viscosity called as sol-gel solution.

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The cotton cloth sheet (75 mm × 50 mm) was dried at 100 °C for 10 minutes in order to remove moisture. For coating, the fabric was immersed for 1 minute in the sol-gel solution. The coated fabric was dried at room temperature and rinsed with water for neutralization of acid. The fabric was dried at 80 °C for 10 minutes and then cured at 100 °C for 30 minutes in a preheated oven. Finally hydrothermal treatment was given to the fabric at 97 °C for 1.5 hour in autoclave to induce the formation of anatase form of titanium dioxide.

C. Photodegradation of Amaranth in photocatalytic reactor

Photocatalytic degradation experiments were carried out in a photocatalytic chamber containing two 15W lamps as source of UV light to evaluate the photocatalytic performance of the sol-gel coated cotton fabric. A dye solution of 50ml with concentration of 10ppm was poured into a beaker having cross sectional area of 86.6 cm^2. The cotton fabric carrying films of TiO_2 were placed in the beaker in such a manner that the total available surface of photocatalyst was 50 mm × 75 mm. The beaker was then placed onto the working area of the photocatalytic reactor. A magnetic stirrer was used to provide mixing. Two UV light sources were then switched on and the solution was irradiated with the ultraviolet light The concentration of the dye at different reaction times were determined by measuring the absorbance intensity at λ_{max} = 520 nm with the help of the UV-Vis spectrophotometer. The decrease in concentration of the amaranth was plotted with respect to time for analysis.

D. Kinetic Modeling

It has been agreed that the expression for the rate of degradation of dyes with irradiated TiO_2 follows the Langmuir –Hinshelwood (L-H) law of heterogeneous photocatalytic reactions. According to L-H model, when initial concentration C_o (ppm) is very small the following pseudo-first order rate equation is followed.

$$\ln\frac{C}{Co} = -kt$$

where k is pseudo- first order rate constant (hr^{-1}) and t is time (hr). A plot of ln (C/Co) versus time represents a straight line, the slope of which upon linear regression equals the pseudo-first order rate constant k (hr^{-1}).

III. RESULTS AND DISCUSSION

The data for photocatalytic degradation of amaranth was recorded. The decrease in concentration of dye was plotted with respect to time and depicted in Figure 1. It is obvious from the figure that the dye concentration decreased effectively with time. There was 67.8 % decrease in dye concentration after 2.5 hours of UV light illumination. The concentration versus time data was best fitted by an exponential equation with regression coefficient as high as 0.997. The value of half-life time ($t_{1/2}$) for the degradation of dye was calculated to be 1.54 hour.

The kinetics of degradation of amaranth was also studied and presented in Figure 2. The obtained data when plotted as ln(C/Co) versus time showed a straight line fit indicating that the degradation followed pseudo-first order kinetics according to the Langmuir –Hinshelwood (L-H) law. The pseudo-first order reaction rate constant calculated was 0.45 hr^{-1}.

Figure 3 compare the results of present study with already reported results of Kumar and Bansal (2010). The nanosized titanium doxide was deposited on inert glass support using solgel process by Kumar and Bansal (2010). The current work showed far better results due to dual effect of adsorption and photodegradation. The cotton fabric acted as an adsorbent in adsorbing the dye molecules from the solution. The adsorbed molecules on the surface of the fabric then came in contact with TiO_2 which caused photodegradation.

The solgel coated cotton fabric acted as semiconductor as well as an adsorbent to give dual effect to the dye removal regardless the characteristics of the dye. The dual effect was capable in increasing the efficiency or performance of the whole degradation system.

Table 1 shows the comparison of half-life time and reaction rate constant of the present work and already reported data.

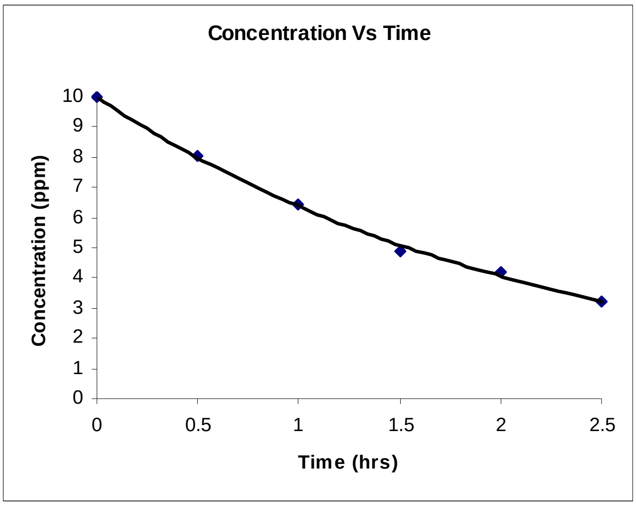

Figure 1: Time effect on degradation of amaranth for sol-gel coated TiO_2 on cotton fabric

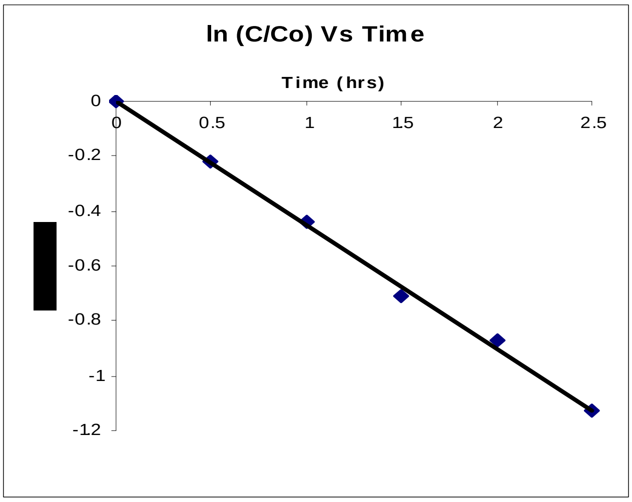

Figure 2: Kinetics of amaranth degradation

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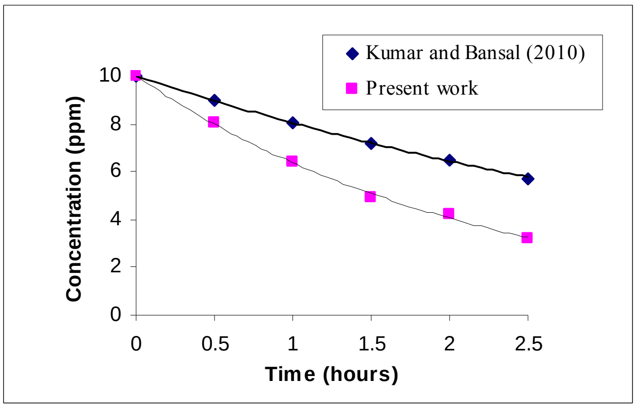

Figure 3: Comparative study

Table 1 Half-life time and reaction rate constant

Study	Half Life Time ($t_{1/2}$), hours	Rate Constant (k), hour^{-1}
Kumar and Bansal (2010)	3.11	0.22
Present work	1.54	0.45

IV. Conclusion

The catalyst was immobilized on cotton fabric using sogel technique, which eliminated the need of filtration of catalyst for further use. It has been observed that combination of adsorption and photodegradation process has much better capability to degrade amaranth dye. The results of the photocatalytic degradation of amaranth showed that sol-gel coated cotton fabric is effective in removing the dye from water with a half-life time ($t_{1/2}$) of 1.54 hour. The degradation kinetics followed the Langmuir –Hinshelwood (L-H) law of heterogeneous reactions. The pseudo-first order reaction rate constant recorded was 0.45 hr^{-1}. The application of the solgel coated cotton should be extended for treatment of industrial wastewater.

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References

[1] Kumar Jatinder., Bansal A., Photocatalytic degradation of amaranth dye over immobilized nano-crystals of TiO_2, In proceedings of international conference on Energy & Environment, University of Cambridge, UK, 2010.

[2] Kumar Jatinder., Bansal A., Sol-gel Derived Films of Nano-crystals of TiO2 for Photocatalytic Degradation of Azorubine Dye., International Journal of ChemTech Research,2(3), 2010, 547-15522.

[3] Kumar Jatinder., Bansal A., Dual Effect of Photocatalysis and Adsorption in Degradation of Azorubine Dye Using Nano-sized TiO_2 and Activated Carbon Immobilized with Different Techniques, International Journal of ChemTech Research, 2(3), 2010, 1537-1543.

[4] Habibi M.H., Esfahani M.N., Egerton T.A., Photochemical characterization and photocatalytic properties of a nanaostructure composite TiO_2 film, International Journal of Photoenergy, 2007, 13653, 1-8.

[5] Mahshid S., Ghamsari M. S., Askari M., Afshar N., Lahuti S., Synthesis of TiO_2 nanoparticles by hydrolysis and peptization of titanium isopropoxide solution. Semiconductor Physics, Quantum Electronics & Optoelectronics, 2006, 9(2), 65-68.

[6] Černigoj U., Lavrenčič Štangar U., Trebše P., Opara Krašovec U., Gross S., Photocatalytically active TiO_2 thin films produced by surfactant-assisted sol-gel processing, Thin Solid Films, 2006, 495, 327-332.

[7] Gupta K. K., Jassal M., Agrawal A.K., Sol-gel derived titanium dioxide finishing of cotton fabric for self cleaning, Indian Journal of Fibre & Textile Research, 2008, 33, 443-450

[8] Valtierra J.M., Cardenas M.S., Reyes C.F., Calixto S., Formation of smooth and rough TiO_2 thin films on fiberglass by sol-gel method, Journal of Mexican Chemical Society, 2006, 50(1), 8-13.

[9] Černigoj U., Photodegradation of organic pollutants in aqueous solutions catalyzed by immobilized titanium dioxide:Novel routs towards higher effeiceincy, PhD thesis, University of Noval Gorica, Graduate School, Nova Gorica, 2007.

[10] Divya N., Bansal A., Jana A K., Surface modification, characterization and photocatalytic performance of nano-sized titania modified with silver and bentonite clay. Bulletin of Chemical Reaction Engineering & Catalysis, 2009, 4(2), 43-53.