



Pelagia Research Library

Advances in Applied Science Research, 2011, 2 (3):280-286



Removal of Indigo Carmine dye by using nanosized Semiconducting Photocatalyst in aqueous media

Vinod S. Shrivastava

Nanochemistry Research Laboratory, G.T.P. College, Nandurbar (M.S.), India

ABSTRACT

The present communication deals with the study of photocatalytic degradation of Indigo Carmine in aqueous suspension of nanosized TiO₂ particles. Photocatalytic degradation of Indigo Carmine have been studied with the help of variety of parameters which are catalyst dose, dye concentration, pH and contact time. The optimum condition for the degradation of the dye was 40 mg/L, pH 8, catalyst dose 60mg/L and contact time 20 minutes. The changes of dye concentration were determined by UV-Visible double beam spectrophotometer at λ_{max} 610 nm in our laboratory. The SEM studies were carried out for morphological features and size of the TiO₂ particles.

Keywords: Photocatalytic degradation, Indigo Carmine, TiO₂, SEM.

INTRODUCTION

Purification of wastewater contaminated with these pollutants is very difficult since they are resistant to conventional treatment techniques. Azo dyes are the largest group of the dyes used for dyeing cotton fabrics in the industry. Cotton is the most widely used fabric among all textile materials, hence azo dyes are discharged frequently and in large quantities into the environment. The color and high COD of effluents from dye house cause serious environmental contamination problems nowadays [1]. In particular, azo dyes represent about half of the dyes used in the textile industry and, as a consequence, a relevant problem of pollution related to the release of these products in the environment is taking place [2]. Although there were several other technologies available for the removal of color and COD from azo dye wastewater such as biodegradation [3], sorption [4-6], electrochemical and oxidative degradation [7-11], chlorine dioxide (ClO₂) catalytic oxidation was a very attractive and useful technique for treatment of dye house effluents [12-14].

In view of the above the present communication deals with the degradation of Indigo Carmine by nanosized TiO_2 particles.

MATERIALS AND METHODS

Materials and Methods

For the present study water soluble Indigo Carmine dye, molecular formula $\text{C}_{16}\text{H}_8\text{N}_2\text{Na}_2\text{O}_8\text{S}_2$, molecular weight (466.35 g/mole) was selected. TiO_2 was provided from Himedia. 200 mg/L stock solution of Indigo Carmine was prepared in 1000ml of distilled water. All chemicals were of analytical grade and used without purification. In 100ml of dye solution of desired concentration, different catalyst dose added and irradiated with UV lamp to provide excitation to TiO_2 . To ensure efficient mixing of semiconductor photocatalyst in the reactor. At specific time intervals suitable aliquot of the sample was withdrawn and analyzed after centrifugation. The concentration of dye was determined on a double beam UV-Visible Spectrophotometer (Systronics-2203) at λ_{max} 610 nm. All the experiments were carried out at room temperature. Structure of Indigo Carmine as shown in fig.1.

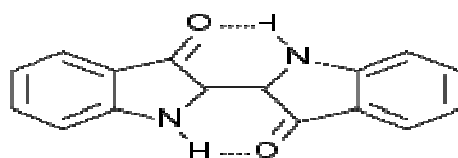


Fig.1: Structure of Indigo Carmine Dye

Instrumentation

The photocatalytic degradation study was carried out in photocatalytic reactor. The reactor consist of mercury lamp, tin reflector and reaction flask. Irradiation was conducted using 400 watt mercury lamp placed inside the tin reflector. The lamp emits pre-dominately UV radiation of 37.4 mW/cm^2 of intensity. Intensity of radiation was measured by Illuminancemeter (Agronics). The pH metric measurements were made on Equiptronics digital pH meter (Model - E610) fitted with glass electrode which was previously standardized with buffers of known pH in acidic and basic medium respectively.

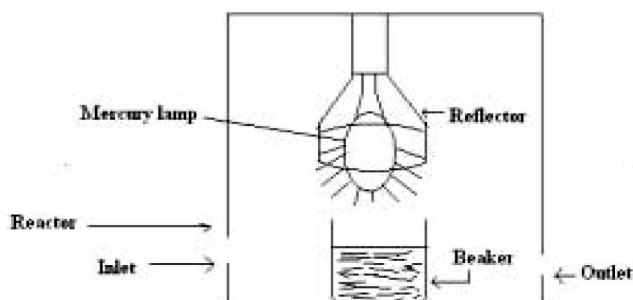
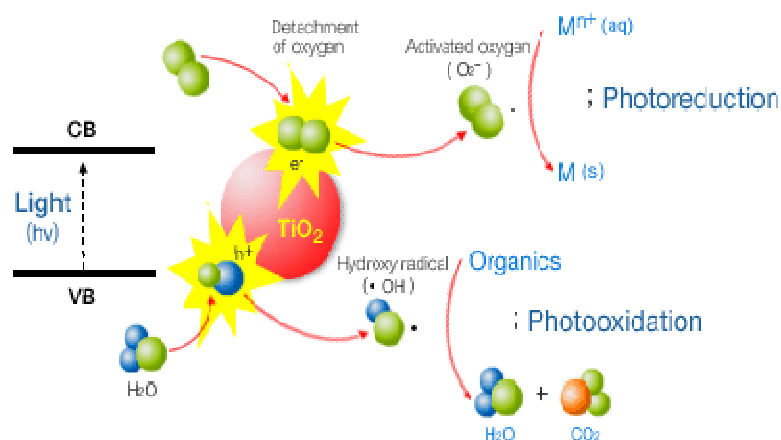


Fig.2(a): Schematic arrangement of Photocatalytic Reactor

Mechanism:*Effect of Catalyst dose*

The effect of photocatalyst dose on the degradation kinetics of Indigo Carmine was investigated employing different dose of varying from 10mg/L to 100mg/L (Fig.3) Photodegradation of Indigo Carmine increases rapidly with increasing the amount of catalyst. The no. of active sites on the TiO₂ surface which in turn increases the no. of OH[•] and O₂^{•-} radicals. It observed that 60mg/L of TiO₂ was the optimum dose for efficient degradation of Indigo Carmine dye.

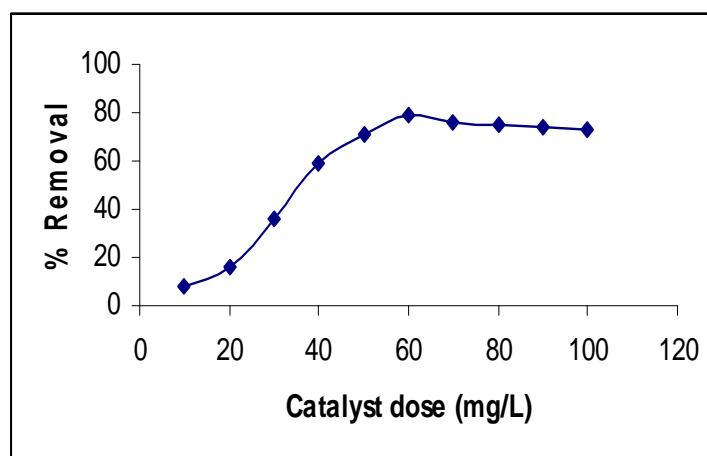


Fig.3 Effect of catalyst dose on percentage removal of Indigo Carmine at dye concentration 40mg/L, contact time 20minutes, pH 8

Effect of dye concentration

The photocatalytic degradation of Indigo Carmine dye has been investigated in aqueous suspension of TiO₂ as a function of irradiation time (fig.4).The rate of photodegradation of Indigo Carmine dye was studied by varying the dye concentration from 10mg/L to 100mg/L. The experiment was carried at fixed pH 8 and catalyst dose 60mg/L. It was found that photocatalytic degradation decreases from 100mg/L to 10mg/L. It observed that 40mg/L of dye concentration was the optimum concentration for efficient degradation of Indigo Carmine dye.

Because for a fixed concentration of active sites remaining the same, the no. of substrate ions accommodated in the interlayer space increases so that the degradation decreases. This may be due to the fact that with increase in initial concentration of the dye, more dye molecules are also adsorbed on the surface of TiO_2 . Thus, increase in the number of substrate ions accommodating in inter layer spacing inhibit the action of catalyst which thereby decreases the reactive OH^\cdot and O_2^\cdot Free radicals attacking the dye molecules and photodegradation efficiency.

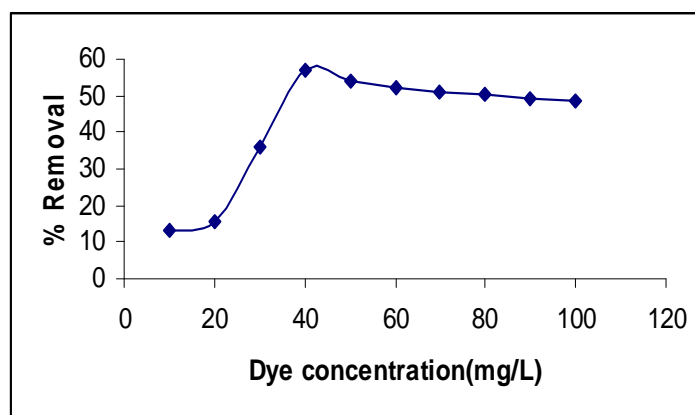


Fig.4: Effect of dye concentration percentage removal of Indigo caramine catalyst dose 60mg/L, contact time 20minutes, pH 8

Effect of pH

The photocatalytic degradation of dye was studied at different pH values as it is an important parameter for reaction taking place on a particulate surface. The role of pH on the rate of photocatalytic degradation of Indigo Carmine dye was studied in the pH range 3-12 at dye concentration 40mg/L and catalyst dose 60mg/L. It was apparent that the rate of degradation of Indigo Carmine with an increase in the pH values up to 8 and beyond the rate of photodegradation becomes constant. This effect may be attributed to more efficient generation of hydroxyl radical by TiO_2 with an increasing concentration of OH^- ion (fig.5).

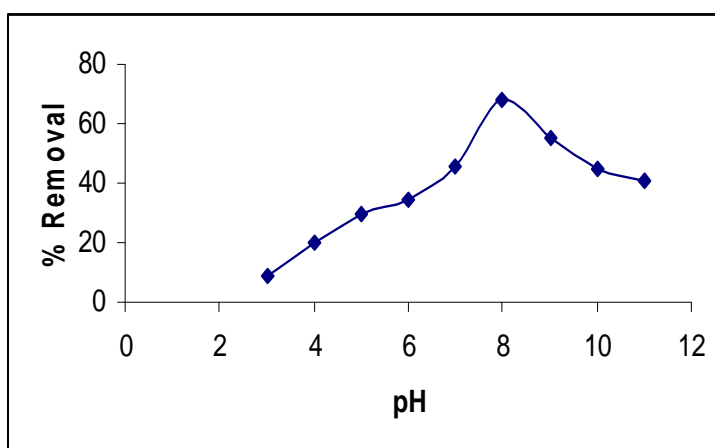


Fig.5: Effect of pH on percentage removal of Indigo Carmine dye concentration 40mg/L, catalyst dose 60mg/L and contact time 20minutes

Effect of contact time

The effect of contact time for the removal of Indigo Carmine dye by semiconductor TiO₂ was shown in fig. 6. The dye was rapidly degraded in the first 20 minutes and then degradation rate decreased gradually and reached equilibrium in about 150 min. It observed that 20 minutes was the agitation time for removal of Indigo Carmine dye. At the beginning, degradation rate was fast as the dye ions were adsorbed by the exterior onto the pores of the adsorbent TiO₂ and were adsorbed by the interior surface of particle. This phenomenon takes a relatively long contact time.

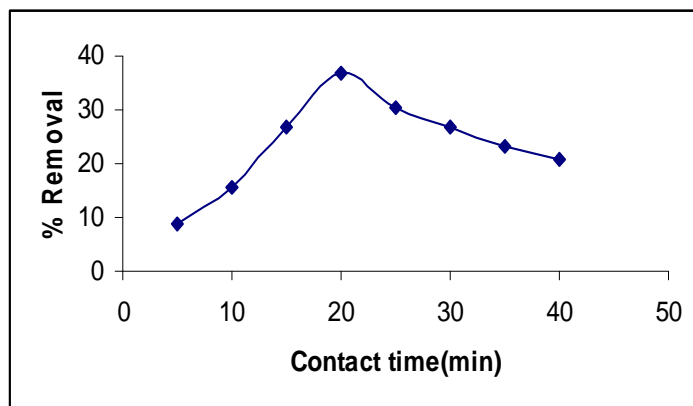
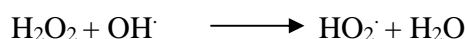


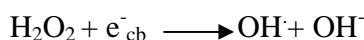
Fig.6: Effect of contact time on percentage removal of Indigo Carmine dye concentration 40mg/L catalyst dose 60mg/L and pH 8.

Effect of Electron Acceptor

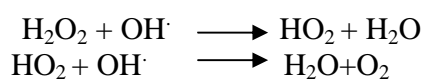
It is observed that molar H₂O₂ concentration is key factor that can significantly influence the degradation of Indigo Carmine dye because H₂O₂ concentration is directly related to the no. of OH[•] radicals generated in the photoassisted reaction. The degradation rate of Indigo Carmine dye increases as the H₂O₂ concentration increases until critical H₂O₂ concentration is achieved. When using a higher H₂O₂ molar concentration, the further generation of OH[•] radical in aqueous solution is expressed as,



Thus, experimental were conducted with different amount ranging from 1 mg/L to 10mg/L at fixed pH 8, dye concentration 40mg/L and catalyst dose 60mg/L. It is apparent that rate of degradation is markedly enhanced in the presence of H₂O₂ additive. H₂O₂ is not only known to inhibit the electron-hole recombination process but also generates hydroxyl radicals on abstraction of an electron from the conduction band.



It was found that the critical molar H₂O₂ concentration for the degradation of Indigo Carmine dye is 4mg/L, the degradation of efficiency remains constant. This is due to hydroxyl radical scavenging effect of H₂O₂.



SEM analysis

Scanning electron microscopy (SEM) is widely used to study the morphological features and surface characteristics of photocatalyst materials. The TiO_2 was analyzed by SEM before and after treatment of Indigo Carmine dye. They show surface texture and porosity of TiO_2 particles.

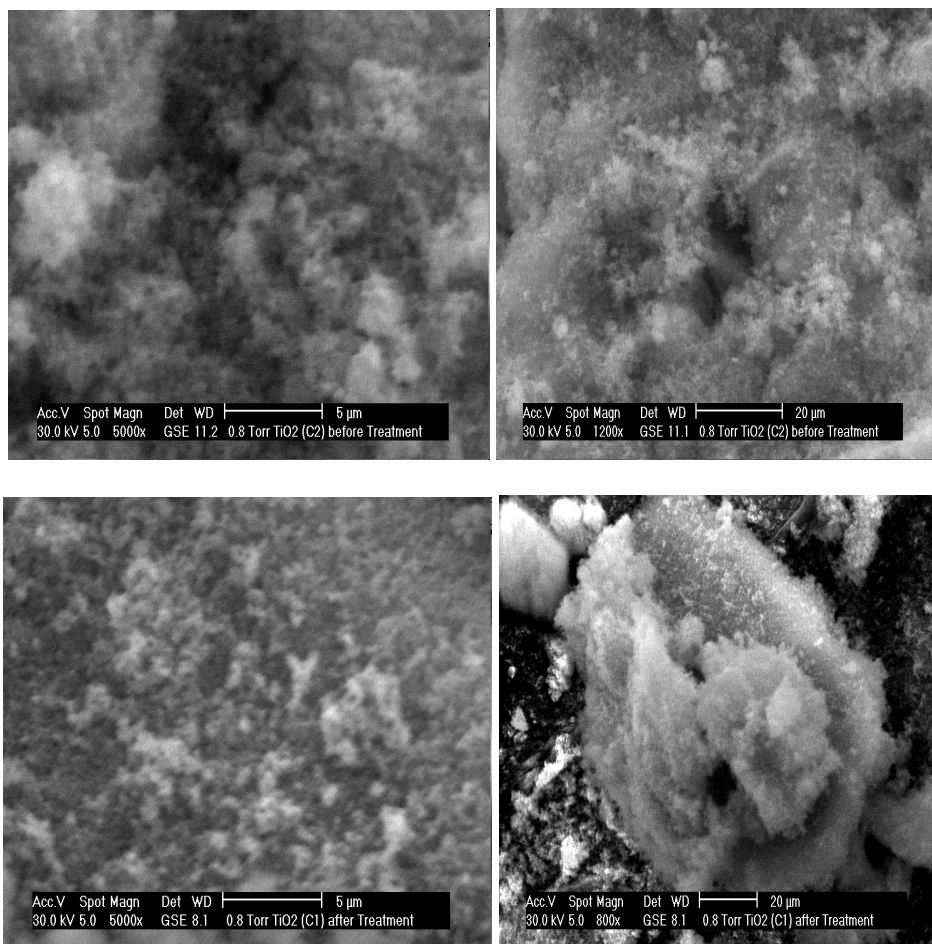


Fig.7: SEM images of TiO_2 and exposed TiO_2 by Indigo Carmine

CONCLUSION

Photocatalytic degradation using nanosized TiO_2 and UV light was successfully applied for Indigo Carmine dye. The degradation rate was increased significantly by increasing the amount of photocatalyst. While on increasing dye concentration decolorisation decreases. Alkaline pH condition have found to be significantly attend the dye degradation. The study shows utilized TiO_2 was nanosized and porous in nature by SEM. The maximum degradation efficiency of dye achieved with the concentration of $\text{UV} + \text{H}_2\text{O}_2 + \text{TiO}_2$. The removal efficiency of Indigo carmine dye was found to be 80.6%.

Acknowledgement

Author is gratefully acknowledged to the Director, SICART, Vallabh Vidyanagar for SEM analysis. Thanks are also due to Dr. Z. Benzo, IVIC, Caracas, Venezuela for useful discussions. Author is also thankful to the Principal G.T.P. College, Nandurbar for providing necessary laboratory facilities.

REFERENCES

- [1] C.L. Hsueh, Y.H. Huang, C.C. Wang, C.Y. Chen, *Chemosphere* **2005**, 58, 1409–1414.
- [2] C. Baiocchi, M.C. Brussino, E. Pramauro, A.B. Prevot, L. Palmisano, G. Marci, *Int. J. Mass Spectrom.* **2002**, 214, 247–256.
- [3] S.Y. Kim, J.Y. An, B.W. Kim, *Dyes Pigments*, **2008**, 76, 256–263.
- [4] A.P.P. Cione, M.G. Neumann, F. Gessner, *J. Colloid Interf. Sci.* **1998**, 198, 106–112.
- [5] C. Namasivayam, D.J.S.E. Arasai, *Chemosphere* **1997**, 34, 401–417.
- [6] A. Mittal, A. Malviya, D. Kaur, J. Mittal, L. Kurup, *J. Hazard. Mater.* **2007**, 148, 229–240.
- [7] B. Mounir, M.N. Pons, O. Zahraa, A. Yaacoubi, A. Benhammou, *J. Hazard. Mater.* **2007**, 148, 513–520.
- [8] G.M. Colonna, T. Caronna, B. Marcandalli, *Dyes Pigments* **1999**, 41, 211–220.
- [9] I.A. Salem, M.S. El-Maazawi, *Chemosphere* **2000**, 41, 1173–1180.
- [10] N. Daneshvar, A.R. Khataee, A.R. Amani Ghadim, M.H. Rasoulifard, *J. Hazard. Mater.* **2007**, 148, 566–572.
- [11] N. Mohan, N. Balasubramanian, C. Ahmed Basha, *J. Hazard. Mater.* **2007**, 147, 644–651.
- [12] C.T. Wang, Q.H. He, P. He, *Environ. Sci. Technol.* **2006**, 29, 65–67 (in Chinese).
- [13] C.T. Wang, Q. Wang, Q.H. He, Z.F. Zhou, *Dyestuffs Coloration* **2006**, 43, 49–55.
- [14] L.S. Shi, H.M. Zhu, Y.Y. Dong, Y.Y. Li, *J. Shandong Univ. (Eng. Sci.)* **2006**, 36, 91–95.