International Journal of Environmental Science: Development and Monitoring (IJESDM)
ISSN No. 2231-1289, Volume 4 No. 2 (2013)

Synergistic effects of sonolysis combined with photocatalysis in degradation of industrial waste water

Isha[1], Anoop Verma[2] and Shilpi Kumari[3]
[1,3]Centre for Energy Studies, IIT Delhi
Hauz Khas, New Delhi, INDIA
[2]Department of Biotechnology and Environmental Sciences, Thapar University
Patalia, INDIA

ABSTRACT

The accelerated photocatalytic degradation of industrial wastewater using titanium dioxide as catalyst activated by ultrasound has been investigated in photocatalytic reactor using ultraviolet light source of 125 W. The effect of number of parameters, such as pH, oxidant concentration and catalyst dose has been examined to study the degradation rates in sonolytic, photocatalytic and sonophotocatalytic processes. The basic reaction mechanism for both sonolysis as well as photocatalysis is the generation of free radicals and subsequent attack by these on the pollutant organic species. If the ultraviolet and ultrasound are operated in combination, more number of free radicals will be available for the reaction thereby increasing the rates of reaction. The ultrasonic activation contributes degradation through cavitation and the turbulence induced by the cavitation phenomena can aid in eliminating the drawbacks associated with photocatalytic oxidation. The results showed that there was synergistic effect between ultrasound and ultraviolet irradiation in the presence of titanium dioxide since the rate constants of the combined process are greater than the sum of the rate constants of the individual processes. It differs from the other treatment processes because wastewater compounds are degraded rather than concentrated or transferred into a different phase. Because the secondary waste materials are not generated, there is no need to dispose of the treated materials. So, we can say that sonophotocatalysis is an excellent technique for treatment of wastewater.

Keywords-sonolysis; photocatalysis; sonophotocatalysis; titanium dioxide

1. INTRODUCTION

Now a day, due to the presence of extremely refractory organic matter in the wastewater stream, the use of conventional wastewater treatment methods are increasingly become challenged. So, now there is a clear need to test and set up the emerging alternative technologies that can deal with highly concentrated and toxic non-biodegradable organic matter. So in this way advanced oxidation process (AOP's) has emerged in the last decade especially for the treatment of industrial wastewater. Recently, considerable interest has been shown by researchers all over the world in the application of ultrasound on the photocatalysis i.e. Sonophotocatalysis, to improve the performance of photo catalytic degradation of organic and inorganic contaminants in aqueous streams. Basically Sonophotocatalysis is the combination of two AOP's i.e. sonication (use of ultrasound) and photocatalysis (use of UV). If the two modes of irradiations (UV and ultrasound) are operated in combination, more number of free radicals will be available for the reaction thereby increasing the rates of reaction.

Sonication contributes degradation through cavitation. Cavitation is the formation, growth and collapse of bubbles in the liquid (P.R Gogate, 2008). The collapse of the bubbles induces localized supercritical conditions: high temperature, high pressure, electrical discharges, and plasma effects. The consequences of these extreme conditions are the cleavage of dissolved oxygen molecules and water molecules (into •H atoms and •OH radicals). From the reactions of these entities (•O, •H, •OH) with each other and with H_2O and O_2 during the quick cooling phase, $HO_2^{\bullet}$ radicals and H_2O_2 are formed. In this molecular environment, organic compounds are decomposed and inorganic compounds are oxidized or reduced (N.J.B Pe´rez and M.F.S Herrera, 2008; S.K.Tang et al, 2012).

Photocatalysis is basically the acceleration of a photoreaction by the presence of a catalyst. Now a days Semiconductors are usually selected as photo catalysts (K.Hashimoto et al, 2005) and among the various semiconductors studied (WO_3, Fe_2O_3, Cu_2O, Bi_2O_3, Fe_2O_3, SnO_2, TiO_2, ZnO, ZrO_2, CeO_2, Sb_2O_4, CdS, ZnS, V_2O_5, ZnO). TiO_2 is most extensively used semiconductor (S.K.Kavitha and P.N.Palanisamy, 2010; I.Grc˘ic´ et al, 2013) because it is inert (chemically and biologically), Stable to corrosion (photo and chemical), having appropriate gap b/w valence and conduction band and absorbs in near UV light (<387nm).

2. MATERIALS AND METHODS

The photo catalyst was TiO_2 P-25 (a mixture of Anatase and Rutile form of titanium dioxide in the ratio of 70:30, procured from Degussa Company, India branch, Bombay with a BET surface area of 50$\pm$ m^2g^{-1} and average particle size of 30 nm). Hydrogen Peroxide (Ranbaxy laboratories) was used as an oxidant. The concentration of H_2O_2 used was 30% in all experiments.

Sample was collected from the core process of a pharmaceutical industry. Then effluent was stored in cold store at 4.C. Wastewater sample was analysed for the COD, BOD and pH. The entire experimental setup was repeated to get the reproducibility of results. Parameters were analysed by methods given in standard methods for the examination of water and wastewater 1989(17th edition) and single distilled water was used throughout the study.

Sample was treated in UV, US and UV+US for seven hours. Samples were withdrawn after one hour and filtered from 0.45 micron syringe filter. COD of the samples were then measured as per the standard methods. Results were then optimized regarding catalyst addition, pH and oxidant addition. Tests were repeated for the getting the reproducibility of results. After Sonophotocatalytic treatment (with optimized conditions), water was filtered and checked for COD, BOD and pH.

Figure 1. *Photocatalytic reactor, sonicator bath and Sonophotocatalytic reactor*

3. RESULTS AND DISSCUSSIONS

Photocatalytic treatment is affected by the following factors:

1) Concentration of the catalyst
2) Operating pH of the process
3) Concentration of the oxidant added

So the Photocatalytic treatment process was optimized for the following deciding factors and these optimized conditions were used for the further actual treatment of the wastewater.

Initial pH was checked and varied to get the optimized value of the pH. Catalyst was added in a wide range from 0.1 to 10 gm/100 ml to optimize the process for maximum pollutant degradation. H_2O_2 was added in the range of 0.25-4 ml/100 ml to check optimum volume for the process. The results showed that the maximum COD reduction was achieved with 0.3g/100ml concentration of catalyst, at pH 4.5 and 0.6ml/100 ml of oxidant. Under these optimum conditions, the maximum degradation was achieved under Sonophotocatalytic treatment of wastewater i.e. 98.5 % after 4 hours of reaction time followed by photocatalytic treatment i.e. 94% after 5 hours and very less under Sonocatalytic process i.e. only 51 % after 5 hours.

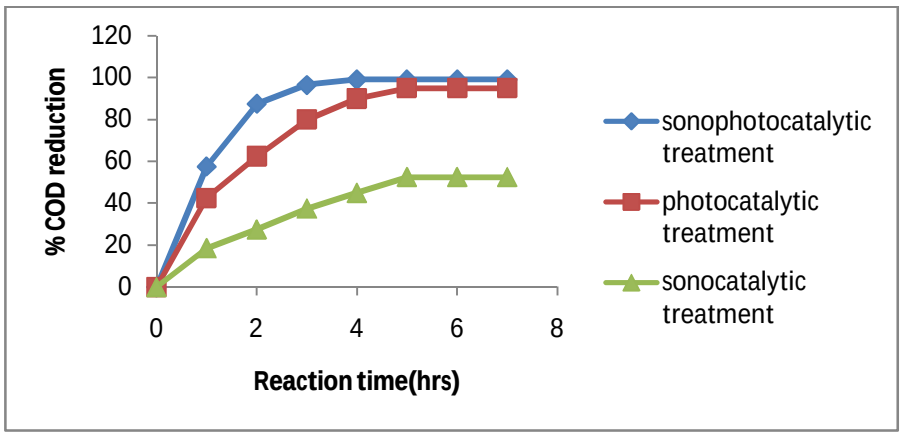

Figure 2. *Showing percentage degradation of wastewater under Sonocatalytic, photocatalytic and Sonophotocatalytic process at optimum condition i.e. 0.3g/100ml TiO_2, 0.6ml/100ml H_2O_2 and at pH 4.5.*

Table 1. *Characteristics of raw effluent and wastewater after Sonophotocatalytic treatment under Optimized Condition.*

S.No	Parameter	Prevailing Range (mg. L-1)	After Sonophotocatalytic treatment (mg. L-1) (Optimized conditions)	Percentage degradation
1	pH	3.65	7.2	-
2	COD	22000	330	98.5
3	BOD	12500	250	98

4. CONCLUSION

Pharmaceutical wastewater has been successfully degraded in the presence of TiO_2. The results of Sonophotocatalytic degradation of wastewater showed that this technology can completely or partially destroy organics at ambient temperature by converting them into various harmless intermediates and end products. So, it could be used as efficient and environmental friendly technique for the complete degradation of recalcitrant organic pollutants which will increase the chances for the reuse of wastewater.

5. REFERENCES

I.Grcˇic´, D.Vujevic´, K.Zˇizˇek and N.Koprivanac (2013), Treatment of organic pollutants in water using TiO_2 powders: photocatalysis versus sonocatalysis, Reac *Kinet Mech Cat*, **109**, *2*, pp. 335–354.

K.Hashimoto, H.Irie and A. Fujishima (2005), TiO_2 Photocatalysis: A Historical Overview and future prospects, *Japanese J. of Applied Physics*, **44**, *12*, pp. 8269-8285 [part1].

N.J.B Pe´rez and M.F.S Herrera (2008), Sonochemical and sonophotocatalytic degradation of malachite green: The effect of carbon tetrachloride on reaction rates, *Ultrasonics Sonochemistry*, **15**, *4*, pp. 612–61.

P.R Gogate (2008), Treatment of wastewater streams containing phenolic compounds using hybrid techniques based on cavitation: A review of the current status and the way forward, *Ultrasonics Sonochemistry*, **15**, *1*, pp. 1–15.

S.K.Kavitha and P.N.Palanisamy (2010), Photocatalytic degradation of Vat yellow 4 under UV/TiO_2, *Modern Applied Sci.*, **4**, *5*, pp 190-142.

S.K.Tang, T.T.Teng, A.F.M. Alkarkhi, and Zhimin Li (2012), Sonocatalytic Degradation of Rhodamine B in Aqueous Solution in the Presence of TiO_2 Coated Activated Carbon, *Intl. J. of Environmental Science and Development*, **3**, *1*, pp. 61-65.