Journal of Basic and Applied Engineering Research
Print ISSN: 2350-0077; Online ISSN: 2350-0255; Volume 2, Number 14; April-June, 2015 pp. 1242-1245

http://www.krishisanskriti.org/jbaer.html

Visible Light Induced Photocatalysis

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Abstract—*Textile industries are one of the biggest users of water in the whole world and are responsible for generating a huge volume of wastewater which is high in pH, COD, BOD, toxicity, colour, turbidity etc. Many techniques of advanced oxidation process have been developed for minimization of the waste produced by these industries but these techniques have several disadvantages including high cost, time consuming and not reliable. Photocatalysis have not only advanced in minimizing the waste from textile industries but have also coped up well with the disadvantages of the AOP techniques. The paper includes the study of different types of photocatalysts and the advantage of visible light induced phtocatalysis over the conventional TiO2. The paper includes the experiments performed with Ag photocatalyst with different catalyst loading. The kinetics and thermodynamics involved in the mechanism of photocatalysis have also been studied. The different parameters like pH, catalyst loading, temperature that are affecting the degradation of dye have also been carefully studied and included*

1. INTRODUCTION

With increasing industrialization the various sectors of processing industries are flourishing which is having an adverse effect on the environment. Among the industries, textile industries are the main partaker in creating pollution. Textile industries are utilizing a huge amount of water at various processing stages. The unused materials in these industries are discharged into the water bodies which are high in color, BOD, COD, pH, temperature, turbidity etc. The flora and fauna are greatly affected due to this. Effluent from textile industries contains different types of dyes, which because of molecular weight and complex structures, show low degradability. The main cause of this pollution is the dyes which have high molecular weight and very complex structures due to which they show low biodegradability. In short, sporadic and excessive exposure to colored effluents is susceptible to a broad spectrum of immune suppression, respiratory, circulatory, and central nervous and neurobehavioral disorders presage as allergy, autoimmune diseases, multiple myeloma, leukaemia, vomiting, hyperventilation, insomnia, profuse diarrhea, salivation, cyanosis, jaundice, quadriplegia, tissue necrosis, eye (or skin) infections, irritation to even lung enema.[1] India is the major manufacturer of textiles which constitute 83 composite mills and 2241 semi composite processing units[2].

2. EXPERIMENTAL PROCEDURE

Preparation of Ag_2CO_3-The Ag_2CO_3 samples were prepared by a typical ion-exchange method.$NaHCO_3$ aqueous solutions (0.05 mol L^{-1}) were added to the 100 ml $AgNO_3$ aqueous solutions (0.05 mol L^{-1}) drop by drop on ice-water bath conditions until the plenty of yellow green precipitations were generated. The precipitations were washed in turn with secondary distilled water to dissolve any unreacted raw materials. Then, the as-prepared Ag_2CO_3 products were atmospheric dried for about two.[3]

3. COMPARATIVE STUDY BETWEEN AG_2CO_3 AND AG_2CO_3 ON ALUMINA

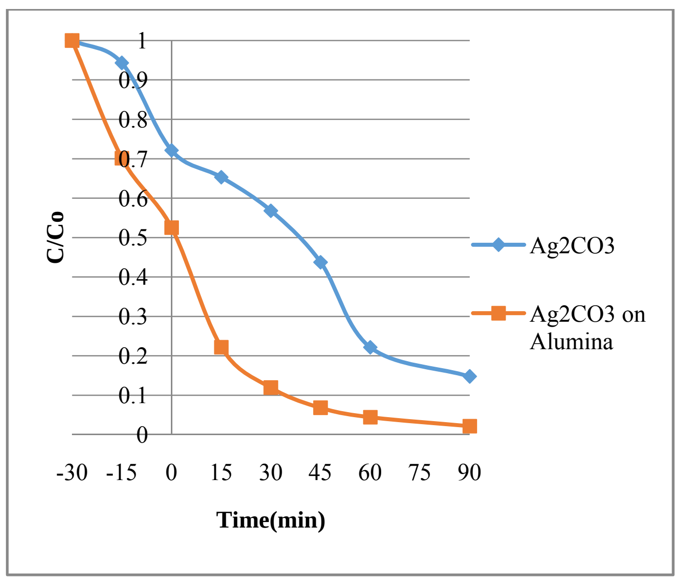

Fig. 1: Comparative study between Catalysts

After experimenting with the catalyst a support has been prepared for the better degradation of dye by increasing the adsorbing properties. The solution of 100ppm dye has been taken for the degradation and 0.3gm each catalyst has been taken and by keeping the other parameters like light intensity, rpm, temperature and pH the comparison has been made and the degradation has been found much better with the help a support. The conclusion that can be made from this is that with the help of a support the adsorption was much faster therefore the degradation was more prominent.

4. EXPERIMENTAL SETUP (PARAMETER STUDY)

To enhance the properties of the catalyst it is loaded on alumina. The size of the powdered Al_2O_3 that is being used is 150 micro meters. The smaller the size the more efficient the catalyst will be because surface area will increase. Then the next important thing will be the bonding of the catalyst on the surface of Al_2O_3.The bonding of the $AgNO_3$ is first done through ultrasonication for 2 hours. The solution of $NaHCO_3$ is put through a burette to the substance formed earlier by putting it on an ice bath. The catalyst that is Ag_2CO_3 on Al_2O_3 is formed. After that the catalyst is calcined at 400C for 2 hours. After carrying out these procedures the photocatalyst that is Ag_2CO_3 on Al_2O_3 will be ready. For the experimental procedure, 100ppm of dye and of the quantity of 125 ml is taken. The experiments are carried out to estimate the different parameters and find a photocatalyst that has the highest efficiency to photocatalytic degradation.

5. CATALYST LOADING

Catalyst loading means the amount of catalyst that is required for the photocatalytic degradation of dye. In the experimentation a catalyst with the ratio of 30/70 of Ag_2CO_3 and Al_2O_3 is prepared. By taking different loading of the catalyst the experiments are performed between 12-2pm.The amounts of catalyst loading taken are of 0.2, 0.3 and 0.5 (gm) respectively in a 100 ppm aqueous solution of dye. The study is performed in a concentrator to enhance the photocatalytic activity. For the experimentation, four beakers of the same size are taken and the dye solution of 125ml is put into it. The photocatalyst is stirred with the dye solution so as to result in proper adsorption in dark for 30 minutes and redox reactions in sunlight. After the adsorption in the dark the solution is taken in proper sunlight and is put into the concentrator for 2 hours and the results are noted after every 15 minutes. The parameters that is varied here is the catalyst loading so all the other parameters need to be kept constant like light intensity, rpm, pH, temperature etc. The light intensity and rpm are maintained at 647.01 W/m_2 and 300. The results are evaluated by performing UV spectroscopy and the optimum among the three is determined. The optimum among them is the 0.3 gm of catalyst loading as it is giving the highest efficiency in terms of degradation of the dye. The conclusion that can be made is that as the catalyst loading increases from 0.2 to 0.3, the amount of catalyst increases and so as the reaction rate of the redox reactions. But after 0.3 a downward trend is observed in the results, it is because of the coverage of active sites for further reactions. The quantity has increased because of which the degradation of the dye lowers. So an optimum amount for the dye is obtained.

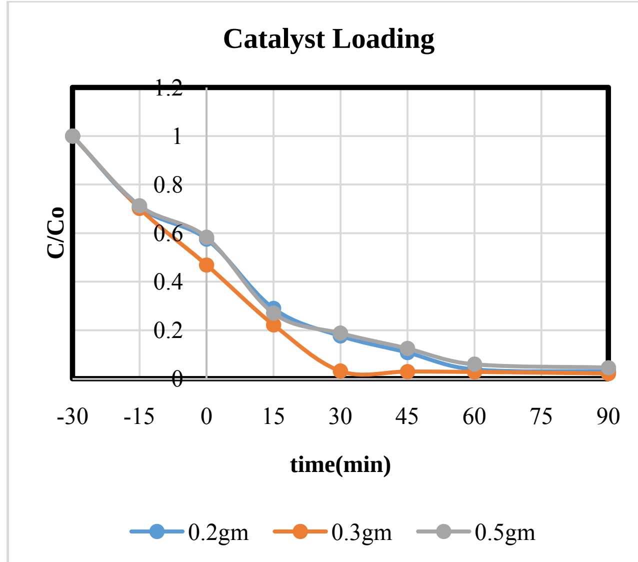

Fig. 2: Comparative Study with different Catalyst Loading

6. TEMPERATURE

The temperature variation also effects the degradation of the dye to a large extent. For the experimentation the temperature that are studied are 30-50, 50-70 and 70-90. The same procedure as earlier is used but in this case the concentrator has not been used so as to maintain a range of temperature. The setup is kept at normal sunlight for 2 hours between 12-2 pm. All the other parameters are kept constant and only the temperature is varied by heating. The main aim for varying the temperature was that to show how the reaction kinetics and the adsorption rate vary with temperature. The conclusion that can be drawn from that is that at lower temperature desorption is the rate limiting step and at higher temperatures adsorption is the rate limiting step. As far as reaction kinetics that is the redox reactions are considered the rate increases on increasing the temperature. The two of the phenomenon are happening together and the one with less dominance will be rate limiting. Between the temperature ranges of 20-80 the reactions and the adsorption both will increase but after that the over-heating takes place and adsorption becomes the rate limiting because of that as no substance is present on the catalyst surface due to less adsorption the redox reactions are not taking place and are not contributing to the degradation of the dye. When the temperature increases above 80 and approaching to the boiling point of water the exothermic adsorption of reactants becomes disfavored and tends to become the rate limiting step. Hence we can conclude from experiments that not much variation can be observed due to temperature variations from 20-80 C in degradation of dye.

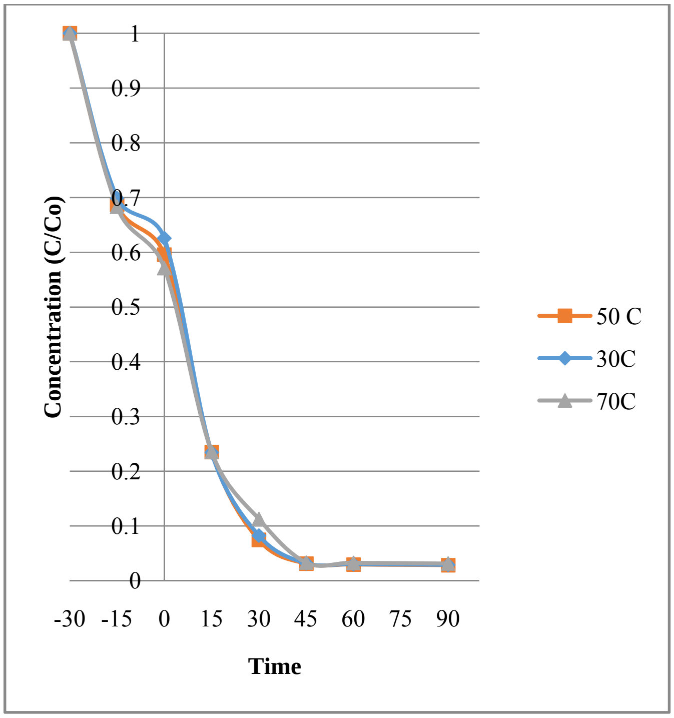

Fig. 3: Temperature Variation

7. LIGHT INTENSITY

The light intensity plays a major role in the photocatalysis. For the experimentation the studies are performed at different time intervals namely 10-12 am, 12-2 pm and 2-4pm.

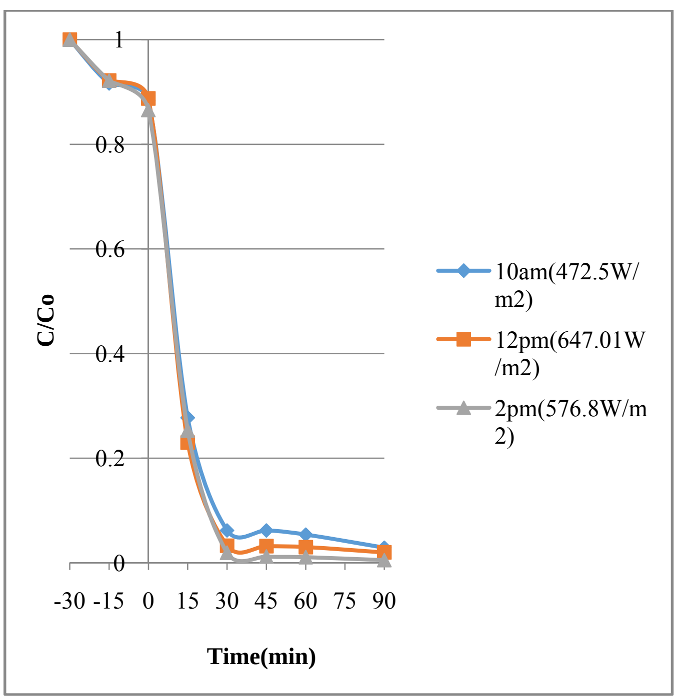

Fig. 4:Light Intensity Variation

The light intensity variation of the three time zones are 472.5 W/m2, 647.01 W/m2 and 576.8 W/m2. All the other parameters are kept constant and the experiment is not performed in the concentrator but in the normal sunlight for 2 hours. The other procedure is same as the other. The results obtained from this shows that the photocatalytic degradation of the dye is more predamant in the time interval of 2-4pm. The results of the degradation of dye varies as per 2-4>12-2>10-12. The conclusion that can be drawn from the results is that as the light intensity increases the photodegradation of the dye decreases as the results of the degradation at higher intensity came out to be lower than that of the lower intensity. This is possible due to the recombination processes that are highly prevalent at higher intensities.

8. PH

The pH of the aqueous solution significantly affects the catalyst including the charge in the particles, the size of the aggregates it forms, and the positions of the conductance and valence bands. The pH does not have much significance in the range of 4 to 10 and to work outside this region is not logical due to environmental and economic reasons. But the importance of this parameter is that when the pH of the industrial wastewater is already acidic or basic. In this case the effect of pH should be taken into account as the process could be enhanced by varying the pH by simple methods like mixing of streams. During the photocatalysis reaction, a multitude of intermediate products are formed which can be affected by pH therefore to use only the rate of decomposition of the original substrate could yield an erroneous pH as the best for contaminant degradation.

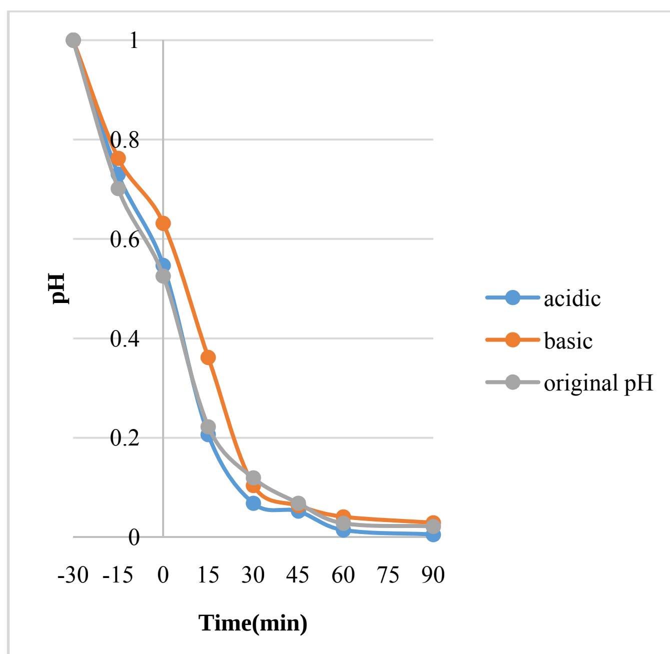

Fig. 5:Effect of pH

9. CONCLUSION

The experimentation on finding the optimum catalyst for wastewater treatment has been performed and the results have been tabulated. The parameter that is catalyst loading have been studied and according to the experimentation performed there is an optimum range of the amount of catalyst to be used this is because the photocatalysis increases as the loading is increased but after a particular amount in this case 0.3gm it has drastically reduced due to the coverage of the active sites. The temperature has very little effect on the photocatalysis rate but a conclusion that can be made is that there is no point on increasing the temperature and it best happens at room temperature. The light intensity has shown some significant differences and there is also an optimum value. The conclusion that can be drawn from that is on increasing the light intensity to a higher value the radiant flux is proportional to the square root of degradation. So at higher intensities the photocatalysis will decrease. There is an optimum light intensity at which the degradation will be maximum.

10. ACKNOWLEDGEMENTS

This paper would not have been possible without the kind support and help of many individuals and organizations. We would like to extend our sincere thanks to all of them. We would like to express our special gratitude and thanks to Prof. S. S. Patel, Head of the dept., and Chemical Engineering for giving us this opportunity to work on this topic.

We are highly indebted to Prof. Leena V Bora, Assistant professor, Chemical Engineering Dept. for her guidance and constant supervision as well as for providing necessary information regarding the project & also for her support in completing the project-report.

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