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Study and compare the photodegradation efficiency of clay-based compound with semiconductor oxide nanomaterials

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ABSTRACT

Improvement of semiconductor oxide nanomaterials play a vital role in photocatalytic activity of photodegradation process. In this article we compare the characterization property of photo catalytic activity of Bentonite clay supported $ZnWO_4$ with heterostructured compound of $BiVO_4 – ZnO$ and $DyVO_4 – ZnO$. The active nanomaterials exhibits high reusability without any loss of photocatalytic property upto four successive stages. Our results give new impact on the performance of photocatalysts on environmental remediation.

Keywords: *Bentonite clay, $BiVO_4 – ZnO$, Photocatalyst, Rhodamine B, Methylene Blue*

1. INTRODUCTION

Most of the semiconductor materials have been used as photocatalysts that utilize solar energy. Photocatalytic process has potential application for environmental purification because of its advantage of using both UV and solar light. In this photocatalytic process the choice of metal oxides is challenging one for greater catalytic activity. This photocatalytic property proves its excellence in special adsorption area for heavy metals and dyes. Here we successfully compare and study the photacatalytic activity by degradation efficiency of some dyes under natural solar energy on environmental basis.

2. EXPERIMENTAL SECTION

2.1 Catalyst characterization for Photocatalytic process

Photocatalytic experiments were worked out on sunny days between 11 am and 12 pm. A 50 ml open borosilicate glass tube reaction vessel of 40 cmheight and 20 mm diameter was taken for the analysis. The intensity of solar light was evaluated using a LT Lutrin LX – 10 ⁄ A Digital Lux meter and the intensity was 1250 × 100 lx. The sensor was always set in the position of maximum intensity. The intensity was nearly constant during the experiments.

2.2 Photodegradation procedure for $BiVO_4 – ZnO$

On a sunny day, a 50 ml of dye solution with $BiVO_4 – ZnO$ is taken in the reaction vessel. The mixture were magnetically stirred for 30 minutes in the dark to attain adsorption − desorption equilibrium between the dye and the catalyst of $BiVO_4 – ZnO$. Irradiation was carried out in the open-air condition. The suspension was aerated by pumping oxygen for complete mixing of the solution. No volatility was observed during the illumination time. The first sample was taken after the dark adsorption. At specific time intervals, 2 ml of the sample was withdrawn and centrifuged to separate the catalyst. A 1 ml centrifugate was diluted to 10 ml and its absorbance was measured at 306, 314 and 285 nm for AV 7, EB and RR 120 dyes respectively. This absorbance represents the aromatic content of the three dyes and its decrease indicates degradation of dye. Solar light intensity was measured every 30 minutes and the average of its also calculated.

2.3 Photodegradation procedure for $DyVO_4 – ZnO$

Photocatalytic experiments were performed on sunny days in a borosilicate glass tube. A 50 ml of dye solution with DyVO4 – ZnO was taken in a reaction vessel and the procedure was followed as we did in the above catalyst activity. Rh –B and TB concentrations were monitored from the absorbances at 259 and 236 nm respectively.

2.4 Photodegradation procedure for natural clay (Bentonite) supported $ZnWO_4$

On a sunny day, all kind of photocatalytic experiments were carried out. A 50 ml of dye solution with Bentonite ZnWO4 was aerated by passing oxygen, there is no volatility during the illumination time. After dark adsorption the first sample was taken. At

specific time intervals 2 ml of sample was centrifuged to separate the catalyst. From that 1ml of centrifugate was diluted to 10 ml and its absorbance was measured at 259 and 293 for Rh−B and MB dyes respectively. This absorbance represents the aromatic content of Rh-B and MB and their decrease indicate the degradation of dye. Every 30 minutes the solar light intensity was measured and its average of each experiment also calculated.

3. RESULTS AND DISCUSSSION

3.1 Photodegradation Activity of $BiVO_4$ − ZnO

Photocatalytic degradation of AV 7 (283 ppm) under different conditions is shown in Figure 1. Dye is resistant to self-photolysis, and for the same experiment with $BiVO_4$− ZnO in the dark, a small decrease (6%) in dye concentration was observed. This is because of the adsorption of dye on the catalyst. AV 7 undergoes 96% degradation in the presence of $BiVO_4$−ZnO under natural sunlight in 75 min. However, prepared ZnO, TiO_2−P25, and $BiVO_4$ produced 77%, 59%, and 72% degradations, respectively in 75 min. This shows that $BiVO_4$−ZnO is most efficient in AV 7 degradation than other photocatalysts. On the basis of the results, it is obvious that the higher photocatalytic activity of $BiVO_4$−ZnO is due to the $BiVO_4$ dopant. To test the efficiency of the catalyst on the degradations of other dyes, we carried out the experiments on the degradation of EB and RR 120 under the same conditions.

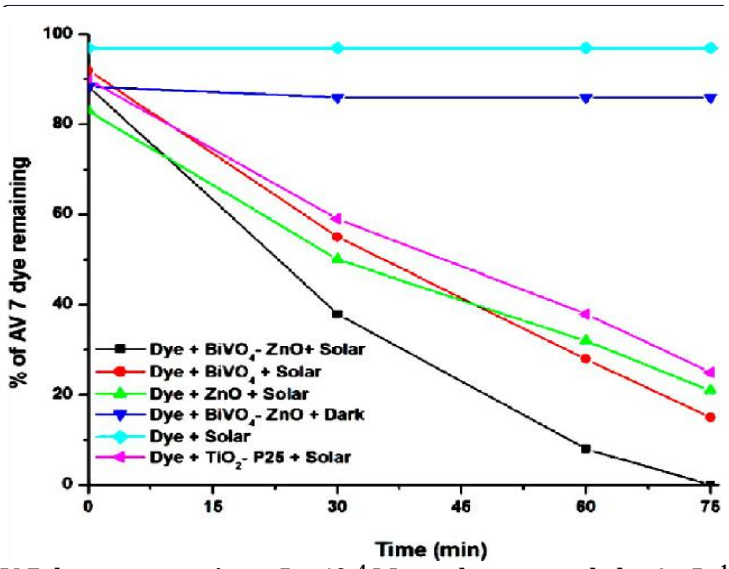

Fig. 1: Primary analysis: AV 7 dye concentration = 5×10^{-4} M, catalyst suspended = 4 g L^{-1}, pH = 7, air flow rate = 8.1 mLs^{-1}, I_{solar} = 1250 × 100 Lux ±100.

3.2 Photodegradation Activity of $DyVO_4$ − ZnO

Photodegradation of Rh-B under different conditions with in- creasing irradiation times is displayed in Fig. 2. Dye is not affected by light. A decrease (8%) in dye concentration in dark with $DyVO_4$-ZnO is due to the adsorption. Rh-B undergoes 98% degradation with $DyVO_4$- ZnO under natural sunlight in 75 min. But, prepared ZnO and undoped $DyVO_4$ shows 76% and 62% degradations, respectively in 75 min. The efficiency of $DyVO_4$-ZnO in photocatalytic activity under sunlight is higher than UV light. These results show that prepared 5 wt% $DyVO_4$-ZnO nanomaterial is most efficient for degradation of Rh-B dye than other photocatalysts under natural sunlight irradiation. Higher photodegradation by $DyVO_4$-ZnO is caused by loaded $DyVO_4$. A 15 wt% of $DyVO_4$/g-C_3N_4 exhibited 96% degradation efficiency for Rh-B in 2 h under Visible light irradiation. Whereas, our catalyst 5 wt% $DyVO_4$-ZnO shows almost complete degradation of Rh-B at 75 min under natural sun light irradiation. To test the effectiveness of the catalyst on the removal of other azo dyes, we performed the degradation of TB under the similar conditions.

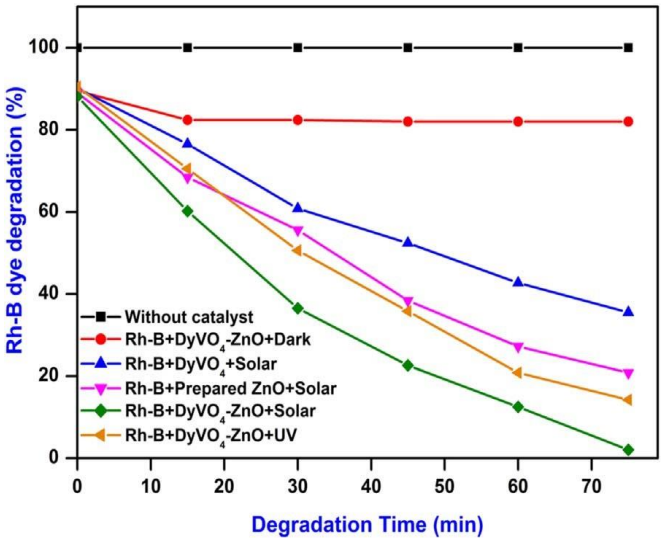

Fig. 2: Primary analysis: Rh-B dye concentration = 3×10^{-4} M, catalyst suspended = 3 g L^{-1}, pH = 7, airflow rate = 8.1 mL s^{-1} and irradiation time 75 min, I_{solar} = 1250 ×100 lx ±100.

3.3 Photodegradation Activity of natural clay (Bentonite) supported $ZnWO_4$

The photocatalytic activity of Rh-B with different photocatalysts under UV irradiation is shown in Fig. 3. About 98% degradation of the dye occurred at the time of 60 min with Bentonite-$ZnWO_4$. But raw Bentonite, prepared ZnO, TiO_2-P25, prepared $ZnWO_4$ gave 30.5, 62.4, 66.2 and 74.2 percentages of degradation under same reaction conditions respectively. This shows that prepared photocatalyst Bentonite-$ZnWO_4$ is more efficient in degradation of Rh-B under UV light than other catalysts. In case of MB dye, 29.5, 67.6, 73.2 and 79.2% of degradations occurred for raw bentonite, prepared ZnO, TiO_2-P25 and prepared $ZnWO_4$ respectively at 60 min irradiation time.

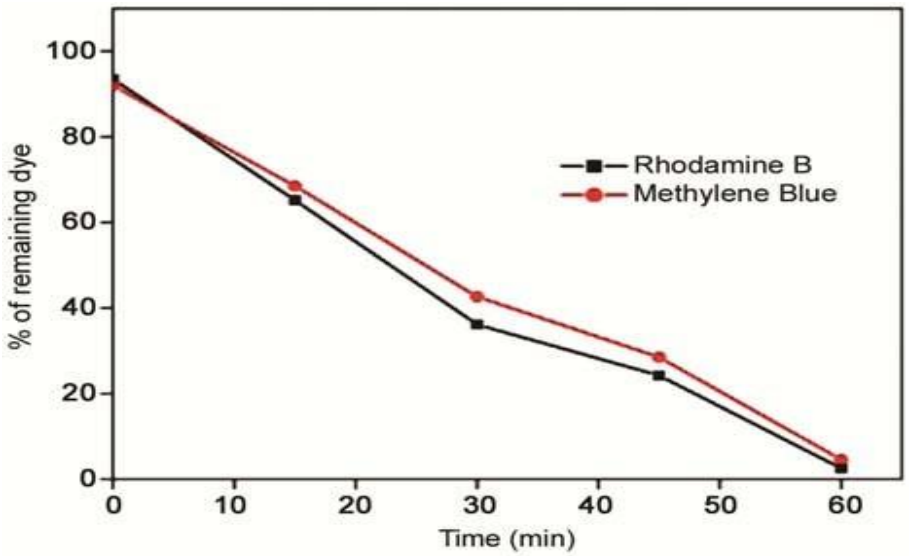

Fig. 3: Photodegradability comparison of Rh–B and MB with different time intervel: dye concentration = 3×10^{-4}M, MB-catalyst =1×10^{-4} M suspended =3 g L^{-1}, pH = 7, airflow rate = 8.1 mL s^{-1}, I_{UV} = 1.381×10^{-6} einstein L^{-1} s^{-1}.

4. COMPARITIVE STUDY OF PHOTODEGRADATION ACIVITY OF SEMICONDUCTOR OXIDE NANOCOMPOSITES

The Photocatalysts of $BiVO_4$ − ZnO and $DyVO_4$ – ZnO are degraded AV 7 and Rh - B respectively under naural sunlight. The Percentage of AV 7 and Rh – B with 12 wt % of $BiVO_4$ – ZnO and 15 wt % of $DyVO_4$ – ZnO were found to be 96 and 98 respectively for 75 minutes irradiation, whereas the photocatalyst of Bentonite − $ZnWO_4$ is degraded Rh-B under UV light. The percentage of Rh - B degradation with 12 Wt % of Bentonite − $ZnWO_4$ were found to be 98 for 6o min. irradiation. Out of three photocatalyst Bentonite – $ZnWO_4$ is more effective in degradation process than the other catalysts in a short period of irradiation.

5. CONCLUSION

The photodegradation study of natural clay supported $ZnWO_4$ was compared with a natural sunlight active photocatalyst $DyVO_4$ – ZnO and hetero-structured $BiVO_4$ − ZnO coupled semiconductor oxide photocatalyst. This study shows that all the three photocatalysts were found to be stable and reusable. This photodegradation results proved that natural clay supported $ZnWO_4$ had the greater efficiency than the other photocatalysts because the decrease in intensity of Bentonite − $ZnWO_4$ makes low combination of electron- hole pairs and remarkable photocatalytic activity. This paper reveals a new and better application for the surface active natural clay Bentonite supported $ZnWO_4$ on the photocatalytic applications.

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