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Photocatalytic Degradation of Anionic Dye using Fe/Tio$_2$ Composite.

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ABSTRACT

Dyeing industry discharges large amount of coloured wastewater into water bodies without proper treatment. There are various methods to treat wastewater, but recently Photocatalytic treatment has been proven effective. So an effective Iron /Titanium Dioxide (Fe/TiO_2) photocatalytic composite has been synthesized by sol-gel method. The synthesized Fe/TiO_2 composite was characterized by scanning electron microscope (SEM), X-ray diffraction (XRD), Energy Dispersive Spectroscopy (EDAX). The photocatalytic degradation study of Fe/TiO_2 composite under UV light was studied using the aqueous solution of anionic dye Methyl Orange. The effect of various parameters such as catalyst loading, pH and initial concentration of the dye on degradation has been investigated. The maximum degradation of Methyl Orange dye concentration in aqueous medium was obtained at pH=5 and 200 mg/l of Fe/TiO_2 composite for 10 mg/l concentration of Methyl Orange dye. Finally, the results prove that photodegradation of Methyl Orange dye in aqueous solution using composite was very effective under UV irradiation.

Keywords: Photocatalytic degradation, Methyl Orange dye, Sol-gel, Fe/TiO_2 composite, UV irradiation.

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INTRODUCTION

Dyeing industries discharges huge amount of colored wastewater which are highly toxic that pollutes the environment. Over the last few decades large scale usage of chemicals in various human activities has grown very fast, particularly in a country like India which has to go for rapid industrialization in order to sustain over growing large problem of population. The current pattern of industrial activity alters the natural flow of materials and introduces novel chemicals into the environment [1]. The major source of water pollution is domestic waste from urban and rural areas, and industrial wastes which are discharged into natural water bodies. Ground water is the largest source of fresh water in developing countries and it is also subjected to such danger [2].Therefore degradation of the dyes in industrial wastewaters has generated considerable attention due to their huge volume of production, slow biodegradation, low decoloration and high toxicity [3].Various physico-chemical treatment methods are widely used for treatment of these wastewaters. Among all treatment methods, photocatalytic degradation is a promising technique, for removal of various toxic chemicals found in wastewater [4-6]. Heterogeneous photocatalytic oxidation is an effective method to remove low concentrations of organic contaminants [7]. Hence, it is of interest to investigate the Photocatalytic degradation of anionic dye using Fe/TiO_2 composite.

MATERIALS AND METHODS

Materials

All chemicals were of analytic grade reagents without further purification and purchased from Merck Company. Titanium Isopropoxide, Ferric Nitrate [$Fe(NO_3).{}_3 9H_2O$]were used as received and purchased from Merck, India and were used without further purification. Methyl Orange dye was obtained from textile industry.Distilled water was used for preparation of dye solutions . The pH of the solutions were adjusted with HCl / NaOH.

Photocatalytic Reactor

The photocatalytic experiments were carried out in batch immersion type reactor. The reactor consists of a long tube made of quartz which was placed inside the glass reactor fitted with standard joint. The reactor consists of 8W low pressure mercury vapor lamp which was placed inside the quartz tube.

Synthesis of Fe / TiO_2 composite

Mix few ml of Titanium Isopropoxide with 2-propanol and distilled water. Then add $Fe(NO_3).{}_3 9H_2O$ solution to it. Mix it well using magnetic stirrer for 4 hrs. Keep this mixture in oven at 100^oC for 10 hrs. Then cool to room temperature. Then heat the mixture at 450^oC for 5 hrs in Muffle Furnace to obtain Fe/TiO_2 photocatalytic composite.

Photocatalytic Degradation of the Dye under UV Irradiation

Experiments were carried out under UV light. To 200 ml of dye solution, a certain amount of catalyst was added and suspension was subjected to UV light irradiation. The aqueous suspension was stirred throughout the experiment. A small quantity of the sample was taken after certain time interval, Fe/TiO_2 composite were separated using centrifuge and the degradation rates were calculated from absorption values of Methyl Orange dye concentration measured using UV-Visible spectrophotometer.

RESULTS AND DISCUSSIONS

Characterization of Fe / TiO_2 composite

Surface morphological studies

The SEM images of Fe/TiO_2 composite depicts the surface features which has been shown in Fig. 2. (a) and (b). Here the particles are agglomerated and are truely spherical in shape. Boundaries of particles are

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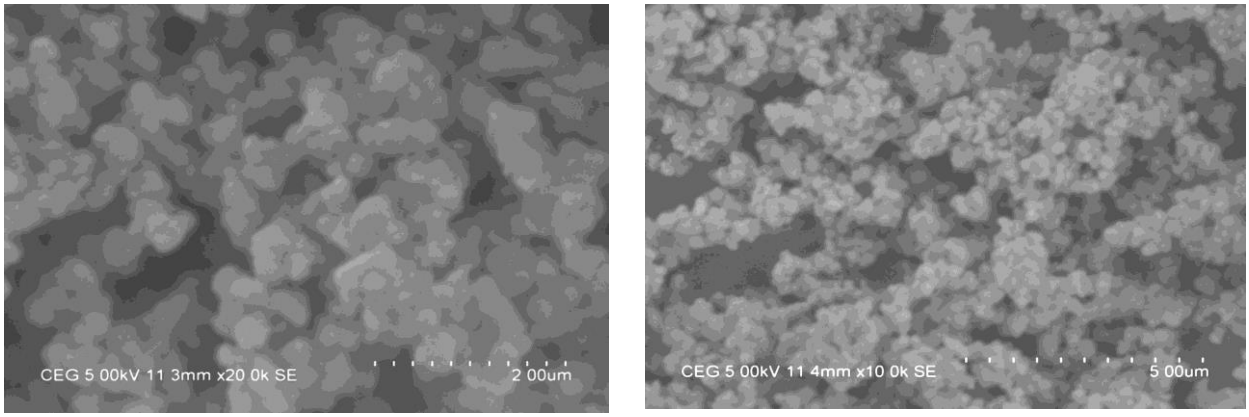
clearly shown in the SEM study of Fe/TiO_2 composite. The surface texture and porosity nature of the composite is observed, this defines Fe/TiO_2 composite as nanoparticles of few nanometer size in the form of nano clusters.



(a) (b)

Figure 2: SEM images of (a) Fe/TiO_2 (2 µm), (b) Fe/TiO_2 (5 µm)

XRD measurement

The XRD results for Fe/TiO_2 composite (Fig.3.) have peaks at 2Θ values of 25.52º, 38.05º, 48.16º, 54.31º, 62.85º,70.42º and 75.35º can be assigned to the diffractions of (101), (112), (200), (105), (204) and (215) which indicates the formation of anatase phase of TiO_2.

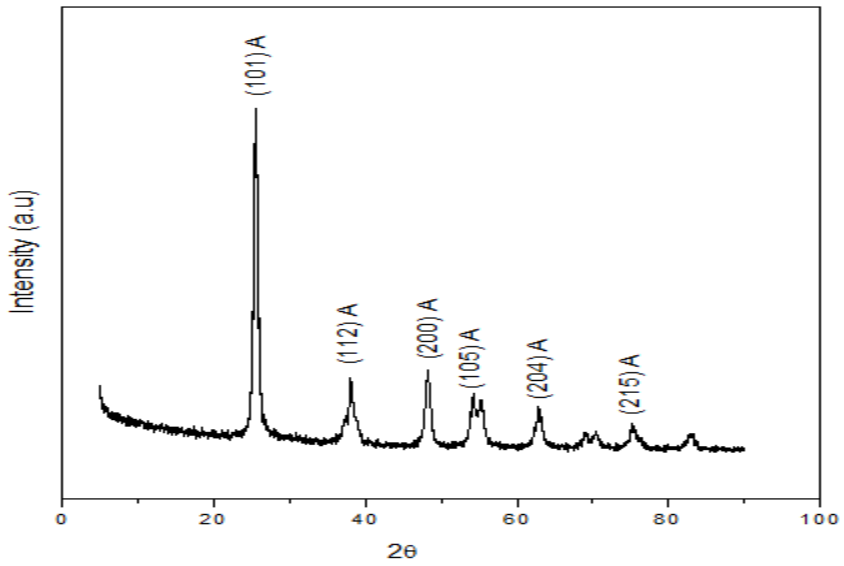


Figure 3: XRD pattern of Fe / TiO_2 composite

EDAX Spectrum

The EDAX spectrum for Fe/TiO_2 composite shows different peaks which clearly depicts the presence of Ti, Fe and O. The EDAX (Energy Dispersive Spectroscopy) analysis of Fe /TiO_2 composite has been shown in Fig. 4.

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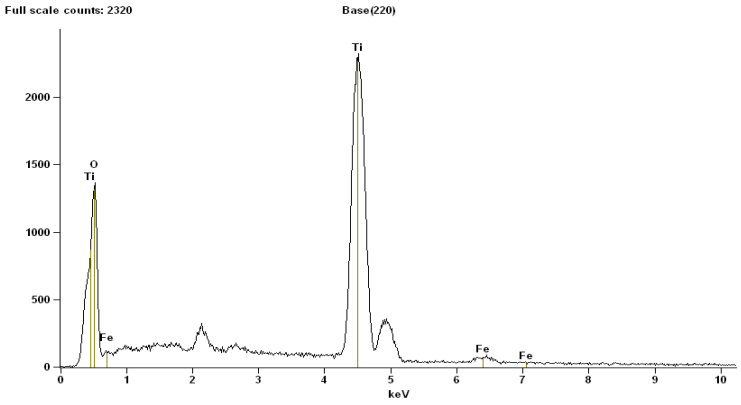

Figure 4: EDAX spectrum of Fe/TiO_2 composite

Photocatalytic Batch Study

Effect of catalyst loading

Batch photocatalytic experiments were carried out using various dosages of Fe/TiO_2 composite (50 to 300mg/l) with constant concentration of 10 mg/l of Methyl Orange dye for 60 minutes (Fig. 5). It was observed that as Fe/TiO_2 composite dose increased, the percentage degradation of dye concentration increased. Above 200 mg/l of Fe/TiO_2 composite dose, there is no significant increase in the degradation of dye. So, 200mg/l of Fe/TiO_2 composite has been considered as an optimized dose for degradation of Methyl Orange dye. The increase in degradation rate with increase in the catalyst loading is due to increase in total active surface area i.e. availability of more active sites on catalyst surface. But higher dose of catalyst results in increase in turbidity of the suspension which decreases the penetration of UV light and hence photoactivated volume of suspension. Therefore, it can be concluded that higher dose of catalyst may not be useful both in view of aggregation as well as reduced irradiation field due to light scattering.

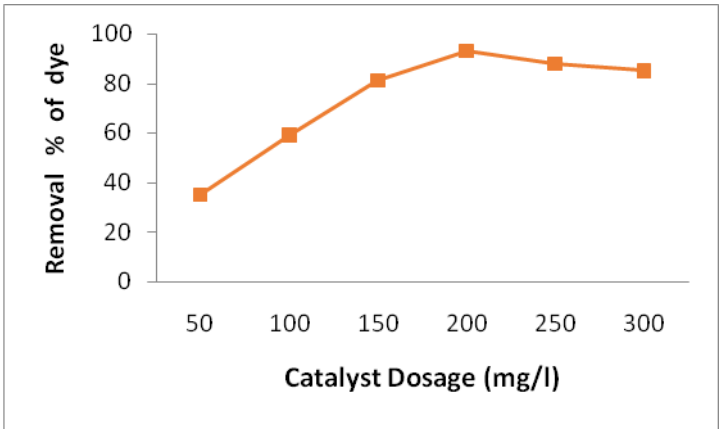

Figure 5: Study of effect of catalyst dosage

Effect of pH

Textile dyeing wastewater is discharged at different pH; therefore it is important to study the role of pH on degradation of dye. In order to study the effect of pH, experiments were carried out at various pH values (2 to 8) at constant dye concentration (10 mg/l) with Fe/TiO_2 composite (200 mg/l). It was observed that the degradation efficiency increases with increase in pH and maximum degradation of 85 % for Fe/TiO_2 composite was observed at pH 5 (Fig. 6). When changing upto pH 8 there is no significant increase in degradation. This shows the degradation efficiency of photocatalyst depends on pH.

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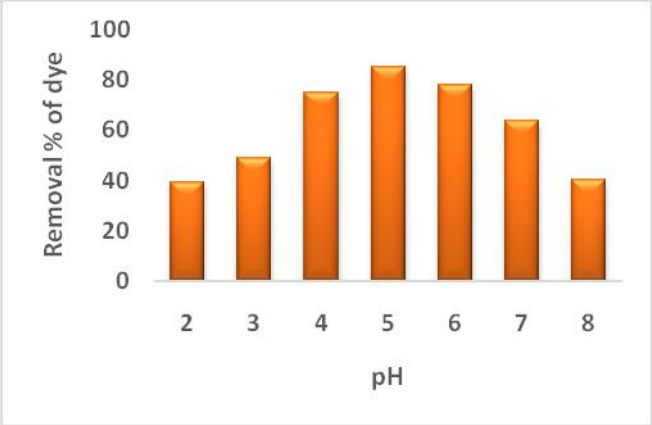

Figure 6: Study of effect of pH

Effect of initial dye concentration

The influence of initial concentration of dye solution has been investigated on the photocatalytic degradation at optimum pH (5) and catalyst dose (Fe/TiO_2 composite =200 mg/l). The dye concentration was varied from 50 to 150 mg/l. The reason behind this behavior may be due to the increase in the extent of adsorption on the catalytic surface which reduces the catalytic activity. It has been observed from the Fig.7. The degradation decreases with increase in dye concentration with the catalyst. At high dye concentration a significant amount of UV light may be absorbed by the dye molecule rather than the catalyst and this may also reduce the catalytic efficiency.

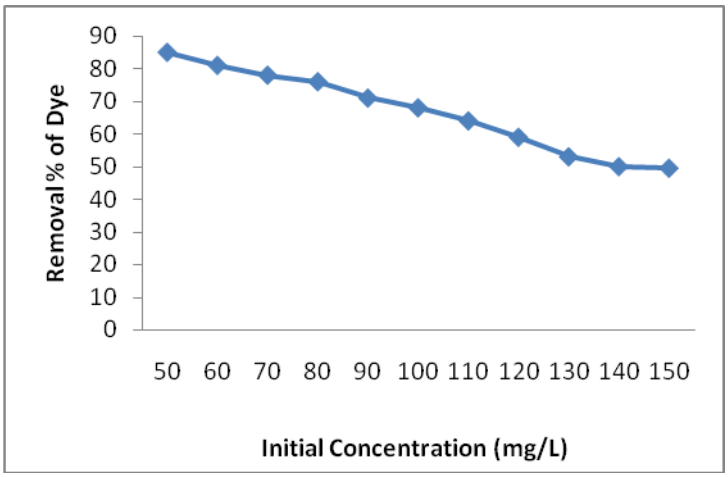

Figure 7: Study of effect of initial dye concentration

CONCLUSION

In this research work, the Fe/TiO_2 composite has been synthesized successfully by sol-gel method and the characterizations clearly depicted the anatase phase of the synthesized Fe/TiO_2 composite. The Fe/TiO_2 composite dosage, pH of the solution and dye concentration plays a significant role in the photodegradation activity. Thus composite dosage = 200 mg/l and pH = 5 was found to be the optimal for 10 mg/l concentration of Methyl Orange dye under the photocatalytic batch study. Thus Methyl Orange dye has been effectively degraded to more extent with Fe/TiO_2 composite along with UV light.

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