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Degradation of Textile Effluent Using Green Technology and Tio_2 Nanocatalyst

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ABSTRACT

The Photocatalytic process is one of the important green engineering concepts employed for treating the waste water from industries. This paper presents an overview of Photocatalytic degradation of textile effluents in industries by titania (TiO_2). TiO_2nanocatalystwas synthesized using sonochemical method. This Nanocatalyst was characterized using SEM, XRD &TGA. An Effluent from the textile contains hazardous compounds such as ethyl sulphonic and sulphonic groups which cause severe water pollution. Photocatalytic degradation using Tio_2nanophotocatalyst based adsorbent as a semiconductor in a batch reactor. Experiments were performed to observe the extent of photocatalytic degradation of textile effluents by analyzing different parameters. The effluents were degraded and nearly 96% of colour reduction was observed. Experiments were also conducted to optimize the amount of catalyst used during this process. This process is a very effective green engineering concept and a cheapest for treating the textile effluents using TiO_2 before disposing it off into water.

Introduction

Water bodies are mainly contaminated due to textile dyes and effluents. Volume of wastewater containing processed textile dyes is ever increasing. Over 7×10^5 ton and roughly 10,000 different types of dyes and pigments are produced annually worldwide. It is estimated that 10–15% of the dye is lost in the effluents during the dyeing process. Water pollution control has importance for both living organisms, which live in water and, those who benefit from water. Many dyes are difficult to decompose before they reach the water source and cause many problems due to their carcinogenicity. Consequently, the removal of these pollutants is necessary from wastewater before their final disposal. One of the common problems of textile effluents is the presence of dye materials, because colour is visible to the public even though the dye concentration is lower than other pollutants, and needs therefore to be removed from the wastewater before it is discharged. There are various chemical and physical processes such as separation of pollutants and chemical precipitation methods, coagulation, electro coagulation and elimination by adsorption on activated carbon, etc., are not destructive as because they only transfer the contaminants from one form to another form, therefore, a different and new kind of pollution problem is being faced which in turn calls for further treatment. Also, due to the stability of modern dyes due to presence of sulphonic and ethyl sulphonic groups, most of the conventional treatment methods such as adsorption technique, Fenton's reagent, coagulation and biological methods for industrial wastewater are ineffective. In the recent years, an alternative method to the conventional ones is the advanced oxidation process (AOP),one of the best technologies based on the generation of very reactive species such as the organic pollutants that are oxidized in a wide range by hydroxyl radicals non-selectively and quickly. The green technology based on advanced aerobic method like photocatalysed oxidation is a very promising for industrial effluent treatment, especially for decolourization of textile effluents. Main aim of this work is to understand photocatalytic oxidation process for the degradation of the effluents in the waste water. The catalyst used for the photocatalytic process is TiO_2 nanoparticles which are prepared using Sonochemical method. The product thus formed due to sonification is in the sizes varying from 20 nm to 40 nm. This green technology, photocatalytic degradation of effluent along with the TiO_2nanocatalyst is highly effective in degradation of dyes.

Material and Methods

Sonochemical method

The diatom was cleaned using concentrated sulphuric acid, and then treated under elevated temperatures. The titania precursor was prepared as in a 10ml absolute solution 0.01mol $TiCl_4$ is dissolved, was slowly added to water (volume ratio of water/ethanol is 1:15). The molar ratio of surfactant to $TiCl_4$ was fixed to 1:0.005.The surfactant dissolved in water/ethanol solution (volume ratio of water/ethanol is 1:8), was slowly mixed with the prepared $TiCl_4$ solution, and then stirred for 30mins.After addition of a known amount of diatom to the resulting solution and then the suspension was sonicated at ambient temperature for up to 6 or 12 hr by a high-intensity ultrasonic probe (20 =kHz, $100W/cm^2$,the wattmeter is used in determining the ultrasonic power of the transducer).These TiO_2nanoparticles were sonochemically treated in the mixture of EG and alkaline solution. The powder was separated by centrifugation, and then washed three times with ethanol, dried overnight under vacuum. Calcination was carried out at 550°C for 5hr in air to remove the organic surfactant.

Characterization of TiO_2 nanoparticles is done using Transmission electron microscope, X ray diffractometer, Thermo gravimetric analyzer.

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Result and Discussion

Transmission electron microscopy

As the TiO_2nanocatalyst is prepared it is examined in TEM for the size. The average crystallite size of pure TiO_2 is about 20 nm to 40 nm.

X- Ray diffraction

The XRD patterns of as-prepared $TiO_2$are shown below in the figue 1.The graph is drawn between the Intensities of light and Theta. In this study, the pure TiO_2present in weight is about 80%. Therefore, the below graphs shows the XRD patterns of the pure TiO_2nanoparticles, which exhibits significant diffraction peaks located at 25.18°, 27.41° and 48.07°. This TiO_2nanoparticles were sonochemically treated in the mixture of EG and alkaline solution, some additional diffraction peaks appears. The TiO_2nanoparticles thus formed are crystalline with face centered cubic (fcc) structure in the solution during the sonochemical method.

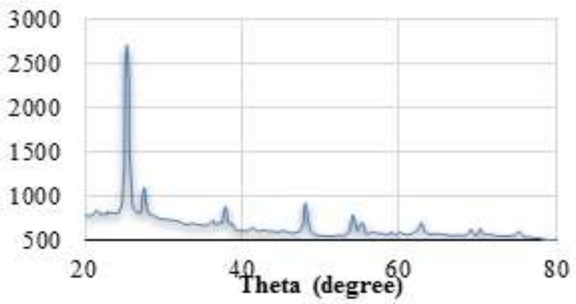

Figure 1. Intensities vs Theta

3 major peaks were obtained at 25.18°, 27.41° and 48.07° which corresponds to the TiO_2 particles with lattices (1 2 0), (2 0 0) & (3 1 1) (JCPDS No: 75-1211).

Thermo gravimetric analysis

The figure 2. gives the characterization that the nanoparticles are TiO_2. from its total weight (%) at 100°C it losses bonded and free in it and on further heating at 360° C the $TiCl_4$precursors are evaporated and only TiO_2 nanoarticles are present and on further the TiO_2 nanoparticles are also evaporated.

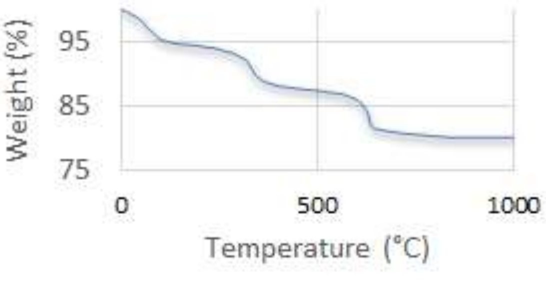

Figure 2. Weight(%) vs Temperature.

Photocatalytic degradation:

The experimental setup for dye degradation is shown below in the figure 3;

Figure 3.Photo-catalytic reactor.

Different industrial textile effluent samples were obtained from the tirupur dyeing industry. TiO_2 nanoparticle was used as photocatalyst. UV-125 lamp (Philips) was used as the radiation source.

Experiments were performed in an annular cylindrical glass tube of 500 ml capacity as shown above. The magnetic stirring is used in maintaining the reaction mixture in suspension. The suspension was left for 30 min in the dark in order to achieve the maximum adsorption of the dye on the semiconductor surface. The irradiation was carried out using a 125 W lamp placed inside cylindrical quartz tube. The light intensity is in the range of 360-400 nm was obtained.The photo-catalytic reactor - cylindrical vessels 330 mm length and 70 mm diameter, along with the inside tube of 330 mm length and 30 mm diameter and closing cap of 335 mm diameter.External water cooling system is provided to remove the heat and the constant temperature is maintained inside the reactor. In all cases, during the experiments 150 ml of dye solution containing the semiconductor powder in an appropriate quantity was magnetically stirred before and during the illumination. At specific time intervals 10 ml samples were withdrawn. To remove TiO_2 particles, the solution was centrifuged for 30-40 min. The changes in the concentration of the dye were obtained from its characteristic absorption at the optimum wavelength by using UV-visible spectrophotometer.

The experiments were carried out for the study the degradation of dyes by employing TiO_2 nanoparticles as catalyst in presence of UV light. The various parameters which affect the degradation efficiency such as catalyst optimization were studied.

Optimization Studies of the Tio_2 Nanocatalyst

The amount of catalyst used is the main parameter for the degradation studies. The effect of catalyst weight (TiO_2) on the rate after 60 min of photodegradation of textile effluent is presented in the below figure 4.

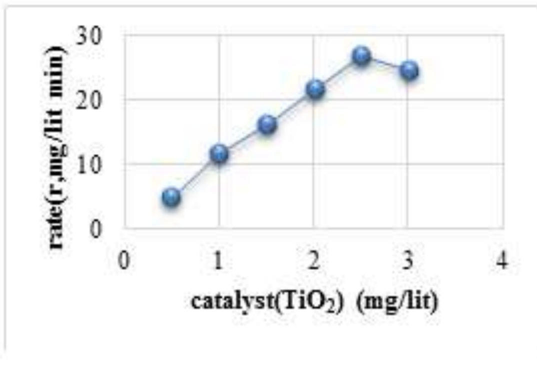

Figure 4. Rate vs Catalyst used.

As the degradation efficiency increases the weight of the catalyst increases up to 2.5g/lit. When the amount of catalyst exceeds 2.5g/lit, the degradation efficiency decreases. As the amount of catalyst increases, the number of available adsorption and catalytic sites on TiO_2 also increases. Hence the degradation efficiency increases. But at concentration above 2.5g/lit of the catalyst the decrease in degradation efficiency may be due to the enhancement of light reflectance by the catalyst. The photo-activated volume of the catalyst shrinks subsequently the light penetration decreases. The optimum concentration of the catalyst was found to be 2.5g/lit for efficient Photodegradation of textile effluent.

Effluents collected from the textile industries were analyzed before and after treatment for the following parameters.

Table 1. Analysis of textile effluents.

S.No.	Parameters	Before Treatment	After Treatment
1	pH	10.6	7.8
2	TDS (mg/l)	2650	870
3	AmmonicalNitrogen (mg/l)	2.8	2.1
4	Nitrite (mg/l)	0.15	0.02
5	Nitrate (mg/l)	6.8	4.3
6	TotalHardness (mg/l)	1073	603
7	PercentSodium(%)	52.44	30.2
8	Chlorides (mg/l)	675	201

The above table shows that the all the parameters related to the textile effluent got reduce drastically within the one hour of experiment and the same catalytic conditions.

Advantages of photocatalysis

i) The process takes place at ambient temperature and pressure.
ii) Complete oxidation of the substances into CO_2 and water.
iii) The oxygen necessary for the reaction is obtained from the atmosphere.
iv) The catalyst is cheap, easily available and can be reused.
v) No waste disposal problem.

Advantages of green technology

i) It is eco-friendly.
ii) Does not emit anything harmful.
iii) Can bring economic benefits to certain areas.
iv) Can slow the effect of pollution and reduce global warming.
v) Most of green technology is costly but here it is cheaper.

Conclusions

From the results of the present work and the relevant literature, one can claim that the photocatalytic treatment of the waste water of the textile industry could be employed as a powerful tool for the textile effluents decolorization and the reduction of the organic content of the liquid waste. Photocatalytic oxidative degradation of textile effluents which contains many synthetic azo dyes with the other textile dyes, has been studied and it gives very fast and the effective photo-decolorization. Photocatalytic degradation of textile effluents was very effective at the optimum catalyst quantity (2.5 g/L). Effect of photocatalytic oxidation process has been studied on different parameters such as temperature, pH, TDS, Ammonical Nitrogen, Nitrites, Nitrates, Percent Sodium, Chlorides and Sulphates,the results tabulated above show the effectiveness of this process.

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