Tungsten Contaning Materials for Heterogeneous Photocatalytic Degradation of Textile Dyes

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Abstract:

The effectiveness of the heterogeneous photocatalytic water cleansing method in breaking down and mineralizing the resistant organic molecules has drawn interest. The underlying mechanism of this process is the accelerated production of very reactive hydroxyl radicals by light, which oxidize organic materials and transform it into inorganic molecules, water, and CO2. The current study uses tungsten-containing photocatalysts (WO3, BaWO4, Ba3Y2WO9) to photo catalytically degrade dyes produced by the textile industry in water. The breakdown of the dyes (Azure B and P-rosaniline hydrochloride) is shown to be dependent on a number of factors, including pH, dye concentration, photocatalyst, concentration, light intensity, and reaction temperature. The photocatalytic process exhibits pseudo-first order kinetics, according to kinetic studies.

I. INTRODUCTION

Water utilities in both rural and urban regions are finding that they must reuse and recycle wastewater effluent in order to supplement our finite freshwater supply, which is now being strained by the fast population expansion (Mitchell et al. 2002). There have been reports of increased worries about environmental risks and public health as a result of wastewater containing harmful organic chemicals. Due to a variety of human activities, dyes—which are notoriously acutely hazardous and bio-recalcitrant—are constantly being added to the aquatic environment? During the dveing process, up to 20% of the colors produced worldwide are lost and discharged as textile effluents. Water recycling is still significantly hampered by the presence of hazardous organic chemicals in wastewater effluent. Large volumes of synthetic dyes are manufactured and consumed, and because of their toxicity and stability, they pose a major danger to human health as well as significant environmental damage. To lessen synthetic dyes' negative environmental effects, a variety of techniques have been developed for their removal from wastewater. At low concentrations, they are widely present in secondary wastewater effluents due to their poor removal during primary and secondary treatment operations.

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In order to break down persistent organic pollutants and produce more biologically degradable and less toxic substances, a heterogeneous photocatalytic oxidation process using a catalyst and sunlight has shown encouraging results. In order to convert a variety of toxic organic compounds, including those that are not biodegradable, into comparatively harmless end products like CO2, H2O, etc., this process primarily relies on the in-situ generation of hydroxyl radicals under ambient conditions. The combined action of the sun as an energy source, a photocatalyst as an oxidizing agent, and an energetic radiation source controls the process of destroying resistant organics. The following reaction is part of the heterogenous photocatalytic process:

Photocatalyst $hv \rightarrow e^- + h^+$

(1)

The strong oxidizing and reducing agents in this reaction are the h+ (hole) and e- (electron) produced at the photocatalyst surface, respectively. While the created electrons cause these contaminants to be reduced and mineralized, the generated hole is in charge of causing oxidation. The current study compares the degradation of binary, ternary, and quaternary catalysts while mineralizing such synthetic dyes using photocatalysts containing tungsten.

II. RESEARCH METHODOLOGY

Comparative research is done on how solar light and tungsten-based photocatalysts (tungsten oxide WO3, barium tungsten oxide BaWO4, and barium yttrium tungsten oxide Ba3Y2WO9) degrade dyes (Azure B and P-rosaniline hydrochloride). The dye stock solutions (AzureB 0.3058g/250ml=1x10-3M and PRosaniline hydrochloride 0.0809g/250ml=1x10-3M) were made in double-distilled water and diluted as needed. Prestandardized HCl and NaOH solutions were added to dye solutions in a beaker to modify the pH.

A digital pH metre (imported pen type from Henna) was used to test the solution's pH. These solutions were mixed with photocatalyst and subjected to light. A solarimeter was used to measure the light intensity (CEL 201). A water filter was utilized to prevent the heat reaction, and the spectrophotometer (Systronics106) was used to record the decrease in optical density of each solution.

III. RESULT AND DISSCUSSION

The dye solution was placed in a beaker, its pH was adjusted, and then the photocatalyst was added. After this solution was exposed to light, the thermal side reaction was stopped using a water filter. At various time intervals, the solution's optical density (O.D.) was measured, and a graph was created by plotting time against (1+logO.D.). Figures 1 and 2 provide the data in a typical run format for PRosaniline hydrochloride and Azure-B, respectively. These showed a straight line, indicating pseudo-first order kinetics for the process. The rate constant was calculated using the formula K=2.303 x slope.

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Figure-1 Typical Run (P-Rosaniline hydrochloride)

Figure-2 Typical Run (Azure B)

Graphical representation for P-Rosaniline hydrochloride

The use of a scavenger indicated that the OH[•] free radical, which is powerful enough to disrupt several dye bonds, was involved in the reaction. Experiments under control demonstrated that the reaction was a photocatalytic degradation process rather than photodegradation or catalytic degradation.

3.1 Effect of pH

The primary component influencing dye degradation is pH. Keeping all other variables equal, it was adjusted between 5.3 and 8.9 for both dyes and all three photocatalysts. With the three semiconductors (WO3, BaWO4, and Ba3Y2WO9), the highest rate of degradation for P-Rosaniline hydrochloride is 8.6, 8.6, 7.3 (Table1, Fig.3), and for Azure B, it is 7.8, 7.3, 7.3 (Table1, Fig.7).



Figure-3 Effect of pH

The concentration of OHions increases with an increase in pH, which might contribute to an increase in OH⁻ free radicals. The rate drops when the pH rises over a certain point for both dyes because of





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the repulsion between the photocatalyst surface's excess OHions and the dye surface's electron-rich content.

3.2 Dye concentration's effect

Using all three photocatalysts, the rate of dye degradation was examined for both colors. Every other element remained unchanged. The rate of degradation for P-rosaniline hydrochloride (Table-1, Fig. 4) and Azure B (Table-1, Fig. 8) was shown to increase up to a certain dye concentration. The rate of degradation rises because there is a greater surface area of dyes available for the OH⁻ free radical to steal an electron from. After a certain point, the solution becomes darker due to the dye's increased concentration, which prevents more photons from reaching the photocatalyst's surface. Consequently, fewer OH⁻ free radicals are generated, which lowers the rate of photodegradation.



Figure-4 Effect of dye concentration (in moles/litre)



Figure-5 Photocatalyst concentration (in g) Graphical representation for Azure B



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3.3 Effect of weight of photocatalysts

The rate of deterioration is shown to be influenced by the photocatalyst's weight. The data are provided for Azure B (Table 1 and Fig. 9) and P-Rosaniline hydrochloride (Table 1 and Fig. 5), where the weight of each of the three photocatalysts was changed while maintaining all other parameters constant. With all three photocatalysts, it was shown that the rate of photocatalytic degradation rises up to a certain point because the exposed surface area of the catalyst grows, producing more OH⁻ free radicals, which in turn causes the rate of reaction to increase. After a certain value (WO3 0.12g, BaWO4 0.18g, Ba3Y2WO9 0.12g), further increases in the weight of photocatalysts result in the production of more OH free radicals, which crowd out and push them to recombine, slowing down the rate of degradation.

3.4 Effect of intensity of light

One of the main factors influencing dye degradation is light intensity. All other elements were kept constant while varying it. For P-Rosaniline hydrochloride (Table-1, Fig. 6) and Azure B (Table-1, Fig. 10), the greatest rate of degradation for all three photocatalysts (WO3, BaWO4, and Ba3Y2WO9) occurs at 37mW/cm2 light intensity. The reason for this is because when light intensity rises, more photons strike the photocatalyst per unit area, producing more hole-electron couples. As the hole removes an electron from OHions, weaker dye bonds break, increasing the quantity of OH free radicals. Higher intensities weren't investigated since they could result in a heat reaction rather than a photocatalytic one.

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Figure-9 Effect of photocatalyst concentration (in gm) Figure-10 Effect of intensity of light (mW/cm2+

Factors	WO ₃	BaWO ₄	Ba ₃ Y ₂ WO ₉
	Azure B	P-Rosaniline hydrochloride	Azure B
Rate Constant (s ⁻¹)	0.92×10 ⁻⁴	0.441×10 ⁻³	0.49×10 ⁻⁴
рН	7.8	8.6	7.3
Concentration of dye (moles/litre)	5×10 ⁻⁶	1×10 ⁻⁵	4×10 ⁻⁶
Photocatalyst concentration (g)	0.12	0.18	0.18
Intensity of light (mW/cm²)	37	37	37

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IV. CONCLUSION

All three photocatalysts extracted the maximum degradation conditions for both dyes, and different computations were used to establish the maximum rate. At pH 7.8, dye concentration 5×10-6 M, photocatalyst weight 0.12 g, and light intensity 37 mW/cm2, the rate of degradation of Azure-B with WO3 was 9.2×10-5 (s-1). Similarly, for Azure-B, the degradation rate with BaWO4 is 4.9×10-5 (s-1) at pH 7.3, the dye concentration is $4 \times 10-6$ M, the photocatalyst weight is 0.18g, and the light intensity is 37mW/cm2. For Barium yttrium tungsten oxide (Ba3Y2WO9), the dye Azure-B degraded at a rate of 8.44×10-4 (s-1) at pH 7.3, with a dye concentration of 5×10-6 M, a photocatalyst weight of 0.12 g, and a light intensity of 37 mW/cm2. The photocatalytic degradation of P-Rosaniline hydrochloride is evaluated under controlled conditions using WO3, BaWO4, and Ba3Y2WO9. The dye degraded with a rate of 4.46×10^{-4} s⁻¹ at pH 8.6, 1×10^{-5} M dye concentration, 0.12 g photocatalyst weight, and 37 mW/cm^2 light intensity with WO₃. With 0.16 g photocatalyst weight, they used BaWO₄ and their degradation rate increased to 7.19×10^{-4} s⁻¹ under similar conditions. The Ba₃Y₂WO₉ sample at pH 7.3, same dye concentration, photocatalyst weight (w) of 0.14 g and same light intensity showed the highest degradation rate of 2.0×10^{-3} s⁻¹. This work demonstrates the superior performance of Azure B dye and the potency of $Ba_3Y_2WO_9$ as a photocatalyst. The study proposes that solar powered photocatalytic degradation and purification methods may provide environmentally friendly means of pollutant degradation and water purification.

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