Comparison of the photocatalytic performance of TiO_2 and La/TiO_2 in textile dye degradation

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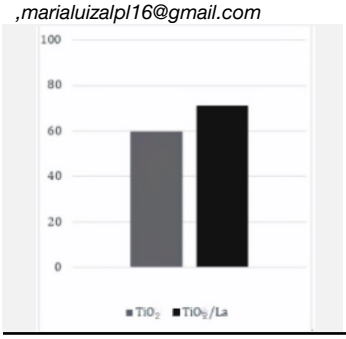

Heterogeneous photocatalysis has proven to be effective in the elimination of various organic and inorganic contaminants, playing a crucial role in environmental decontamination. The purpose of the present experiment was to apply and compare two catalysts, La/TiO_2 and TiO_2 aiming to evaluate their effectiveness as photocatalytic agents in degrading quimacryl red dye. The results indicated that both catalysts showed efficacy, suggesting their viability for application.

Introduction

Environmental issues represent a major global concern due to human activities. These problems include climate change, loss of biodiversity, and pollution of air, water, and soil. These issues negatively impact ecosystems, human communities, and the planet's health. To address these challenges, rigorous environmental policies, sustainable technologies, sustainable industries, and conservation of natural habitats are necessary. Coordinated global action is essential to ensure a sustainable future for generations to come.

In the textile industry, production processes often result in water pollution due to the use of dyes. These dyes are released into factory wastewater, contributing to water pollution. Dyes may contain harmful chemicals, affecting aquatic organisms and local ecosystems. To tackle this issue, more sustainable production practices and efficient wastewater treatment technologies are needed. [1]

One such method is Advanced Oxidative Process (AOP), which is a wastewater treatment technique that has been effective in removing organic contaminants from wastewater. It is an innovative and effective approach that utilizes the generation of hydroxyl radicals to promote the degradation of organic pollutants, contributing to environmental preservation and reducing the negative impacts of these effluents on nature. [2]

There are various AOP methodologies, one of which is heterogeneous photocatalysis that occurs through the activation of semiconductor photocatalysts, such as titanium dioxide (TiO_2), by UV or visible light. This process generates highly oxidizing hydroxyl radicals, which can degrade organic contaminants present in water. Hydroxyl radicals act by oxidizing pollutants, transforming them into less harmful compounds such as carbon dioxide, water, and harmless ions. [3]

The main objective of this study is to evaluate and compare the photocatalytic performance of textile dye degradation using TiO_2 and La/TiO_2.

Material and Methods

Synthesis

Initially, 1 g of dye was measured and transferred to a 1000 mL volumetric flask. Then, distilled water was added to the flask until reaching the meniscus. Subsequently, the solution was fractionated and diluted in distilled water successively until its absorbance approached 1 nm. For the synthesis of La/TiO_2, a dopant proportion of 0.5% was utilized in TiO_2. The precursor solution was added to the TiO_2 (Evonix), and sonicated for 10 minutes, then the suspension was dried at 75 °C for 12 hours and calcined at 450 °C for 4 hours.

Characterization

The catalyst has been characterized by Gas Sorption Analysis (BET). The gas sorption analyzer (Novatouch LX2, Quantachrome) allowed the determination of the BET surface area and the analysis of the pore volume and distribution. The samples were subject to vacuum degassing pretreatment at 200 °C for 2 hours in order to remove moisture and volatile compounds from their surfaces.

Reaction

When this point was reached, two duplicates of TiO_2 and La/TiO_2 were prepared. In each beaker, 100 mL of the solution containing 0.1 g of the respective catalyst were added. Subsequently, all duplicates were transferred to a reactor and stirred for 30 minutes. A sample of each solution was withdrawn with a syringe and transferred to a cuvette, passing through a filter, for the first absorbance analysis. After this step, the solutions were reintroduced into the reactor, where they were kept under stirring and exposed to UV light. Every

30 minutes, samples were collected until completing the fifth reading for each duplicate of each catalyst.

Results and Discussion

Table 1 shows the values obtained for the specific surface area, volume and pore radius for the catalysts prepared.

Table 1. Specific surface area, volume and pore radius.

Catalyst	S_BET ($m^2 \cdot g^{-1}$)	Pore volume ($cm^3 \cdot g^{-1}$)	Average pore radius (nm)
La/TiO_2	8.446	0.024	6.873
TiO_2	3.384	0.012	9.254

The samples have a specific surface area of 3-10 $m^2 \cdot g^{-1}$. The average pore diameter is in the range of 2-50 nm, characterizing them as mesoporous. The adsorption isotherms are of type IV-H1, which is typical of mesoporous systems. This indicates the presence of a pore network formed of spherical agglomerates.

During the photocatalytic experiment, absorbance data of the solution were collected, which were used to generate the graph presented in Figure 2. This graph compares the variation in absorbance from the initial absorbance (absorbance at time 0) over time, in the photocatalytic reaction.

It is observed that both photocatalysts showed activity for the degradation of dye. The addition of lanthanum to titanium dioxide promoted better performance of the photocatalyst, which was already expected, as the addition of metals in small quantities reduces electronic recombination in the photocatalyst, which leads to better photocatalytic activity.

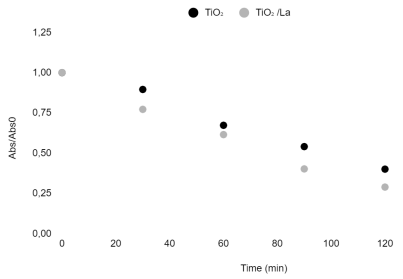

Figure 2: Comparison between the performance of catalysts.

In the study of kinetics it is verified that the mechanism follows the kinetics of pseudo-first order Langmuir-Hinshelwood. The TiO_2 had an apparent specific reaction rate of 0.0071h^{-1} and La/TiO_2 of 0.0102h^{-1}. After 120 minutes of reaction, the dye degraded 59.95% using TiO_2 and 71.10 % using La/TiO_2 (graphic abstract).

Conclusion

The experiment was successfully concluded, demonstrating the effectiveness of both the catalysts in degrading the quimacryl red dye and the addiction the lanthanum in titanium dioxide improves the photocatalytic performance.

Acknowledgments

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