Application of TiO_2 and Bi/TiO_2 in the photodegradation of textile dye

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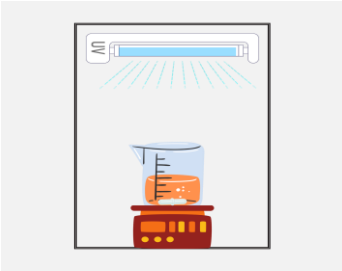

The textile industry is one of the main sources of water pollution due to the improper disposal of contaminated effluents with high organic load and dyes. One promising method to combat this problem is the advanced oxidative process (AOP). Among the AOPs, the one that stands out the most is the heterogeneous photocatalysis process. The objective of this work was to study heterogeneous photocatalysis using Titanium dioxide + Bismuth catalyst in the degradation of dye diluted in water. The photocatalytic activity in the degradation of the red dye was shown to be effective using the catalyst studied.

Introduction

Environmental problems caused by the textile industry are an increasingly pressing global challenge that directly affects life on the planet. Due to the various processing stages of a fabric, a large volume of effluents with a high organic load and presence of pollutants is discarded without proper treatment, significantly contributing to water pollution. A common pollutant in the textile industry is dyes, which, when present in effluents released into waterways, cause high turbidity, directly affecting the biogeochemical cycles of local aquatic life, reducing the incidence of sunlight [1,2].

Given this scenario, the implementation of the Advanced Oxidation Process (AOP) for water treatment and decontamination is essential. Among AOP processes, heterogeneous photocatalysis is a particularly noteworthy approach. This method involves the decomposition of substances in solution or gas, using a solid catalyst that, when activated by light (in the case studied, ultraviolet light) uses light energy to generate pairs of electrons and electronic holes, which can react with molecules of organic matter compounds, leading to their decomposition [3,4].

The objective of this study is to investigate the Titanium Dioxide (TiO_2) Catalyst doped with Bismuth Metal (Bi) for the degradation of synthetic effluents, specifically the Quimacryl Red Dye (textile), through heterogeneous photocatalysis.

Material and Methods

In the synthesis of Bi/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 min. The suspension was then dried at 75 °C for 12 h and calcined at 450 °C for 4 h.

Upon reaching this point, two duplicates of TiO_2 and TiO_2 + Bi were prepared. Each beaker was filled with 100 mL of the synthetic solution containing 0.1 g of the respective catalyst. Subsequently, all duplicates were transferred to a reactor and stirred for 30 min. A sample of each solution was withdrawn with a syringe and transferred to a cuvette, passing through a filter, for the first absorbance analysis.

A synthetic solution of dye was prepared by dissolving 1 g of the red dye quimacryl in 1 L of water at room temperature.

The photocatalytic tests with UV light emission were conducted using 0.1 of the catalyst in 100 mL of dye solution (graphical abstract) The reactions occurred in duplicates at room temperature. Samples were collected by a pipette, filtered through a 45 µm Millipore membrane, and measured in the spectrophotometer every 30 min of stirring.

The quantitative determination of the chemical elements present in the samples was performed by X-ray fluorescence (XRF) analysis on a (Epsilon 1, Malvern Panalytical). The catalysts were also characterized by physical nitrogen adsorption (Novatouch LX2, Quantachrome). The analysis allowed the determination of the BET surface area and the analysis of the pore volume and distribution. The catalysts were subject to vacuum degassing pretreatment at 200 °C for 2 h to remove the water from the surface of the solid.

Results and Discussion

The chemical compositions of the samples determined by XRF are reported in Table 1.

Table 1. Composition of the catalysts.

Catalyst	Bi (% w/w)	Ti (% w/w)	Others (% w/w)
Bi/TiO_2	1.050	98.329	0.621
TiO_2	-	99.223	0.777

Table 2 shows the values obtained for the specific

surface area, volume and pore radius for the catalysts prepared.

Table 2. 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)
Bi/TiO_2	3.268	0.017	12.932
TiO_2	3.384	0.012	9.254

The samples have a specific surface area of 3 $m^2 \cdot g^{-1}$. 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.

The results of the photocatalytic tests are present in Figure 1. It is observed that both photocatalysts demonstrated activity for the degradation of the dye. The addition of bismuth to titanium dioxide resulted in enhanced performance of the photocatalyst, which was anticipated, as the incorporation of metals in small quantities reduces electronic recombination in the photocatalyst, thereby leading to better photocatalytic activity.

In the kinetic study, it is verified that the mechanism follows the pseudo-first order Langmuir-Hinshelwood kinetics. The TiO_2 had an apparent specific reaction rate of 0.0071 h^{-1} and Bi/TiO_2 of 0.0131 h^{-1}.

Following a 120 min reaction period, the degradation of the dye was 60% for TiO_2 and 77% for TiO_2/Bi (Figure 2).

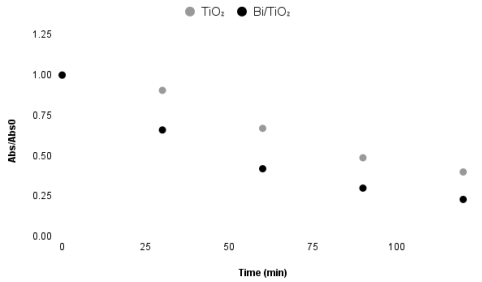

Figure 1. Photodegradation of quimacryl red dye using TiO_2 and Bi/TiO_2.

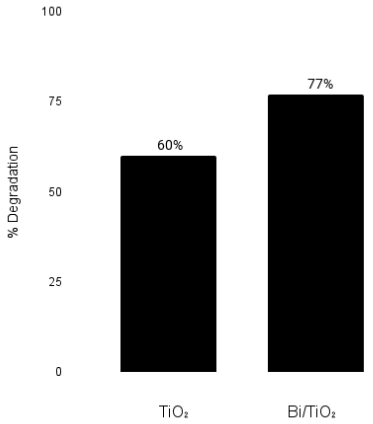

Figure 2. % degradation of dye at photocatalysis process.

Conclusions

The Bi/TiO_2 catalyst demonstrated superior efficiency in the photodegradation of the dye compared to pure TiO_2. This indicates that the metallic bismuth doping enhanced the performance in the photocatalytic process.

Acknowledgments

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References

[1] KUNZ, A. et al. Novas tendências no tratamento de efluentes têxteis. Química Nova, v. 25 (2002) p. 78.

[2] ARAÚJO. Karla Santos de, ANTONELLI. Raissa, GAJDECZKA. Beatriz, GRANATO. Ana Claudia. MALPASS, Geoffroy Roger Pointer, Ambiente e Agua - An Interdisciplinary Journal of Applied Science, [S.L.], v. 11 (2016), p. 387.

[3] BRITO, N. N.; MARINHO SILVA, V. B. Processo Oxidativo Avançado e sua aplicação ambiental. REEC - Revista Eletrônica de Engenharia Civil, v. 3 (2012).

[4] ALBUQUERQUE, M. V. DA C. et al. Remoção de cianobactérias e cianotoxinas presentes em águas de reservatórios eutrofizados por processos oxidativos avançados (POAS). Brazilian Journal of Development, v. 6 (2020), p. 61234.