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Iron oxide nanocatalyst with titanium and silver nanoparticles: Synthesis, characterization and photocatalytic activity on the degradation of Rhodamine B dye

Pâmela Cristine Ladwig Muraro¹, Sérgio Roberto Mortari², Bruno Stefanello Vizzotto¹, Gabriela Chuy³, Cristiane dos Santos², Luis Fernando Wentz Brum² & William Leonardo da Silva^{1*}

Nowadays, there is a growing concern about the environmental impacts of colored wastewater. Thus, the present work aims the synthesis, characterization and determination of photocatalytic activity of iron oxide (Fe_2O_3) nanocatalyst, evaluating the effect of hybridization with titanium ($\text{TiNPs-Fe}_2\text{O}_3$) and silver ($\text{AgNPs-Fe}_2\text{O}_3$) nanoparticles, on the degradation of Rhodamine B dye (RhB). Nanocatalysts were characterized by XRD, SEM, TEM, FTIR, N₂ porosimetry (BET/BJH method), zeta potential and DR5. Photocatalytic tests were performed in a slurry reactor, with the nanocatalyst in suspension, using RhB as a target molecule, under ultraviolet (UV) and visible radiation. Therefore, the photocatalytic activity of the nanocatalysts (non-doped and hybridized) was evaluated in these ideal conditions, where the $\text{AgNPs-Fe}_2\text{O}_3$ sample showed the best photocatalytic activity with a degradation of 94.1% ($k = 0.0222 \text{ min}^{-1}$, under UV) and 58.36% ($k = 0.007 \text{ min}^{-1}$, under visible), while under the same conditions, the $\text{TiO}_2\text{-P25}$ commercial catalyst showed a degradation of 61.5% ($k = 0.0078 \text{ min}^{-1}$) and 44.5% ($k = 0.0044 \text{ min}^{-1}$), respectively. According with the ideal conditions determined, reusability of the $\text{AgNPs-Fe}_2\text{O}_3$ nanocatalyst was measured, showing a short reduction (about 8%) of its photocatalytic activity after 5 cycles. Thus, the Fe_2O_3 nanocatalyst can be considered a promising catalyst in the heterogeneous photocatalysis for application in the degradation of organic dyes in aqueous solution.

Dyes are substances with high application potential in the most diverse areas, mainly to color the final products of textile, precious stones, leather, paper, plastics and food. For example, it is estimated that there are more than 100,000 synthetic dyes, with an annual production of more than 700,000 tons worldwide, generating a significant amount of wastewater¹. In addition, these colored waters are characterized by complex aromatic compounds, making their biodegradation difficult, becoming an environmental liability. Thus, advanced processes are needed to promote their correct treatment in order to meet environmental norms and legislation².

In this context, the Advanced Oxidative Processes (AOPs), highlighting the heterogeneous photocatalysis, becomes an attractive alternative, since they are technologies with potential to oxidize a great variety of complex organic compounds³, using a highly oxidant and less selective species (the hydroxyl radical, $^{\bullet}\text{OH}$), capable of mineralize many organic compounds⁴. Thus, the heterogeneous photocatalysis involves the photoactivation of a semiconductor (catalyst), under visible or ultraviolet radiation, with energy equal to or greater than band gap energy⁵, promoting oxy-reduction reactions on the catalytic surface and thus the degradation of organic pollutants.

Among the most used catalysts are titanium dioxide (TiO_2), cadmium sulfide (CdS), zinc oxide (ZnO), zinc sulphide (ZnS), tungsten trioxide (WO_3), tin dioxide (SnO_2) and iron oxide III (Fe_2O_3)⁶. However, these catalysts

¹Universidade Franciscana - Programa de Pós-Graduação em Nanociências Rua Silva Jardim no 1323, Santa Maria, RS, 97010-491, Brasil. ²Instituto de Química - Universidade Federal do Rio Grande do Sul Av. Bento Gonçalves no 9500, Porto Alegre, RS, 91501-970, Brasil. *email: w.silva@ufn.edu.br

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