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Influence of the Cr loading in Cr/MCM-41 and TiO_2/Cr/MCM-41 molecular sieves for the photodegradation of Acid Orange 7

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ABSTRACT

MCM-41 materials were modified with different Cr contents and then loaded with Ti by the wet impregnation method. The samples were characterized by XRD, XRF, N_2 adsorption, UV–vis DR and TPR. Their photocatalytic activity was evaluated for the degradation of an Acid Orange 7 (AO7) aqueous solution irradiated by UV–vis and only visible light. The presence of Cr^{6+} species highly dispersed on the MCM-41 structure had a significant influence on the photoactivity. With respect to the samples only loaded with Cr, a theoretical loading of 3.5 wt.% allowed an AO7 degradation percentage of around 70%. Higher loadings result in the incremented presence of Cr^{3+} inactive species, as clusters or α-Cr_2O_3 nano-particles, producing no notable increase in the photoactivity. For its part, the presence of Ti in the samples with lower Cr loadings causes an increase in the AO7 degradation which could be associated to a heterojunction effect between active Cr^{6+} species and the titania. For the samples with higher Cr loadings, the lack of synergism could be due to the increased presence of inactive Cr^{3+} species that avoid this expected interaction.

1. Introduction

Industrial dyestuffs including textile dyes are recognized as being an important environmental threat because they consume considerable amounts of water during the dyeing and finishing operations. Due to the scarce freshwater resources, new tighter regulations concerning wastewater discharges have been established in many countries [1]. The most used dyes on the textile and printing industries are the azo-compounds which are suspected to be human carcinogens as they form toxic aromatic amines [2–4]. Taking into account that they cannot be adequately treated by conventional biological process, intensive investigations on new treatment techniques of these wastewaters have been conducted. In this sense, the called advanced oxidation processes (AOPs) have emerged. Among them, the heterogeneous photocatalysis is one of the highly effective methods used on the remediation and treatment of a wide variety of organic pollutants and microbial substances due to their ability to produce a complete degradation of them. A photocatalytic degradation reaction is usually conducted for dissolved compounds in water, at mild temperature and pressure condition, using UV-illuminated semiconductors powder without the requirements of expensive oxidants. A semiconductor is commonly characterized by the energy gap between its electronically populated valence band and its largely vacant conduction band [5]. This band gap determines the wavelength required for excitation of an electron from the valence band to the conduction band. The most studied photocatalyst due to the important results obtained with their use is the TiO_2 [6–8] whose band gap is around 3.2 eV. Thus, TiO_2 requires UV light to be excited and become capable of photo-oxidation [9]. Moreover, with the use of TiO_2 some limitations in the performance of a conventional photocatalytic reactor should be taken into account since they affect the process development. The main limitations are: (1) the low surface area of TiO_2 particles ($50 \pm 15\ m^2/g$) that besides, when they are used in aqueous suspensions tends to form aggregates which provokes a higher decrease in the surface area affecting the process efficiency and (2) the small size ($\sim$0.5 μm) of the TiO_2 particles that does not facilitate their recovery from the effluent wastewater [10]. On the other hand, taking into account that the UV light is not only expensive but also harmful to aquatic life, it emerges the need to develop photocatalysts capable of working in visible light. Thus, the possibility to use solar radiation as a source of energy allows classifying heterogeneous photocatalysis as a sustainable technology.

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