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Photodegradation Efficiencies in a Photo-CREC Water-II Reactor Using Several TiO_2 Based Catalysts

DOI 10.1515/ijcre-2016-0024

Abstract: This study reports phenol degradation using several TiO_2 photocatalysts (DP25, Anatase 1, Hombikat UV-100, Anatase 2) in a Photo-CREC Water-II Reactor. The physicochemical properties of the photocatalysts used, such as crystallinity, superficial area, and pore size distribution are reported. Reactor efficiencies are calculated using both Quantum Yields (QYs) and Photochemical and Thermodynamic Efficiency Factors (PTEFs). This is accomplished using phenol and phenol intermediate photoconversion rates. This allows the determination of hydroxyl radical consumption rates, at every step of the photodegradation process. With these data, and with the absorbed photon rates, energy efficiencies are calculated. It is shown that for the best performing photo catalysts the maximum QYs reach 50 % levels. These favourable photoconversion efficiencies confirm the critical importance of having available highly performing photocatalysts and photoreactors, such is the case of Photo-CREC Water-II Reactor unit.

Keywords: heterogeneous photocatalysis, reactor efficiency, phenol, OH radicals, photons, water

1 Introduction

Heterogeneous photocatalysis is a tertiary water treatment process belonging to the Advanced Oxidation Processes (AOP) based on the production of OH free radicals. Photocatalysis shows a significant potential for being used in the cleaning of air, water, for hydrogen production and for cancer treatment, among other applications (Ahmed et al. 2011; Alfano et al. 2000; Andreozzi et al. 1999; Augugliaro, Palmisano, and Schiavello 1991; de Lasa and Serrano, 2009; Chong et al. 2010).

The Photo-CREC Water-II Reactor (Salaices, Serrano, and de Lasa 2001; Salaices, Serrano, and de Lasa 2002) has been designed and improved to carry out the conversion of several organic and inorganic compounds. This reactor displays promising quantum efficiencies close to 100 %. The importance of energy efficiency assessments for various reactor configurations has been emphasized in the technical literature in recent years (Serrano et al. 2009 and 2010; Brandi et al. 2003; Martin, Baltanas, and Cassano 1996; Sun and Bolton 1996). Nonetheless, energy efficiency determination remains a challenging area given the different variables involved in its calculation. These variables are reaction rates, reaction mechanisms, kinetic parameters, adsorption constants and radiation absorbed by the solid semiconductors.

The Photochemical Thermodynamic Efficiency Factor (PTEF), first introduced by, Serrano and de Lasa (1997), has been used to obtain the reactor efficiencies for the different TiO_2 photocatalysts. The PTEF determination requires that all the hydroxyl radicals be accounted for in the photoconversion of phenol. This is the case, because they are the main species contributing to the photocatalytic conversion of phenol. The quantum yield (QY), another useful efficiency parameter can also be computed with this information (de Lasa et al. 2016)

Many semiconductors have been shown to display photocatalytic activity. Nonetheless, TiO_2 in the anatase form seems to be the most beneficial one given its high stability, good performance and low cost. The photodecomposition power of TiO_2 has been shown to be effective for a wide variety of organic compounds present in water. Degussa P25 (DP25) TiO_2 has been proven to be the most active catalyst so far (Ahmed et al. 2011; Bakardjieva et al. 2005; Cassano and Alfano 2000; Choi 2006; Colmenares et al. 2006; Diebold, 2003, Fujishima, Rao, and Tryk 2000; Fujishima and Zhang 2006; Fujishima, Zhang, and Tryk 2008; Hoffmann et al. 1995; Karvinen and Lamminmäki 2003; Kitano et al. 2007; Linsebigler, Lu,

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