

# A COMPARISON OF SLURRY AND IMMOBILIZED TiO<sub>2</sub> IN THE PHOTOCATALYTIC DEGRADATION OF PHENOL

F.V. SILVA<sup>†</sup>, M.A. LANSARIN<sup>†</sup> and C.C. MORO<sup>‡</sup>

<sup>†</sup> Chemical Engineering Department, Federal University of Rio Grande do Sul (UFRGS)

R. Eng. Luis Englert, s/n. CEP: 90040-040 - Porto Alegre - RS - BRAZIL, marla@enq.ufrgs.br

<sup>‡</sup> Solids and Surfaces Laboratory. Institute of Chemistry, Federal University of Rio Grande do Sul (UFRGS) – Postal Box 15003; CEP 91501-970 - Porto Alegre – RS – BRAZIL, celso@iq.ufrgs.br

**Abstract**— The photocatalytic degradation of phenol was studied using slurry and immobilized TiO<sub>2</sub> as catalysts in order to compare the specific reaction rate constants,  $k_s$  and  $k_p$ . Losses from phenol evaporation, the time necessary to reach adsorption equilibrium, irradiation effects and photolysis rates were quantified.  $k_s$  was determined under rate-optimizing operating conditions, and  $k_p$  was determined using the amount of immobilized catalyst mass that gave the maximum pollutant degradation rates.  $k_s$  was two times larger than  $k_p$  when the calculations were made on catalyst mass basis. Experiments performed to study catalyst deactivation showed that  $k_p$  was approximately one-half of its initial value after 18 hours of phenol photodegradation. Also, among the photocatalytic degradation reactions of rhodamine B, tetracycline and phenol, the ratio of  $k_s$  to  $k_p$  was between 2.1 and 5.3 when the calculations were made on catalyst mass basis.

**Keywords**— Phenol; Rhodamine B; Tetracycline; Photocatalysis; TiO<sub>2</sub>

## I. INTRODUCTION

Many studies of the photodegradation of phenol catalyzed by TiO<sub>2</sub> illuminated with UV and near-UV light have been reported, and the phenol degradation pathways in the UV/TiO<sub>2</sub> system are well documented (de Lasa *et al.*, 2005; Gorska *et al.*, 2009). The data in Table 1 indicate pseudo-first order kinetics for phenol photodegradation in slurry reactors. Even in studies employing identical catalysts and initial phenol concentrations, the reported pseudo-first order specific reaction rate constants differ significantly, limiting the usefulness of the data.

The studies presented in Table 1 were conducted in slurry reactors. When slurry reactors are operated as photocatalytic reactors, the catalysts must be kept separate from the degraded products; this requirement leads

to significant additional costs in reactor operation. However, the use of immobilized catalysts in photocatalytic reactors can simplify their operation and reduce their operational costs.

Several studies have compared the decomposition of substrates using suspended and immobilized catalysts (Li *et al.*, 2010; Grieken *et al.*, 2009; Scotti *et al.*, 2009; Ochuma *et al.*, 2007a; Cho *et al.*, 2005; Ling *et al.*, 2004; Mehrotra *et al.*, 2005; Dijkstra *et al.*, 2001). However, these studies reached different conclusions. Slurry systems were variously reported to be more efficient, less efficient, and as efficient as the immobilized systems.

To assist in the scaling-up of photocatalytic reactors, this study aims to establish the differences between the effects of suspended and immobilized catalysts on the decomposition of a substrate.

Preliminary experiments were carried out to confirm that the disappearance of phenol was only caused by photocatalytic degradation. To test this, phenol losses by evaporation, the time to reach the adsorption equilibrium, irradiation effects and photolysis rates were measured. The optimum catalyst loading conditions for the adopted configuration were then identified, and the reaction rate of the slurry batch reactor was determined. Measurements of the slurry catalyst were compared to those of the immobilized catalyst. Catalytic activity losses were also studied.

## II. METHODS

All measurements presented in this work were repeated three times, and the averages of the observations are reported.

### A. Materials and reactants

Experiments were carried out in a 1 L glass cylindrical reactor, which was jacketed, covered with aluminum foil and enclosed in a wooden box with a built-in fan.

**Table 1:** Literature values of phenol photocatalytic degradation using batch slurry reactors with TiO<sub>2</sub>.

Author	UV Source	Reactor Volume	Initial Phenol Concentration	C <sub>cat</sub>	k (min <sup>-1</sup> )	$\frac{k}{C_{cat}}$ ( $\frac{L}{min g_{cat}}$ )
Chun <i>et al.</i> , 2000	500 W	500 mL	100 mg L <sup>-1</sup>	2.5 g L <sup>-1</sup>	0.0448	0.01792
Peiró <i>et al.</i> , 2001	125 W	100 mL	100 mg L <sup>-1</sup>	1.5 g L <sup>-1</sup>	0.099	0.066
Cesconetto, 2002	80 W	2 L	70 mg L <sup>-1</sup>	1.0 g L <sup>-1</sup>	0.282	0.282
Cesconetto, 2002	125 W	2 L	70 mg L <sup>-1</sup>	1.0 g L <sup>-1</sup>	0.016	0.016
Silva, 2007	125 W	1 L	50 mg L <sup>-1</sup>	0.3 g L <sup>-1</sup>	0.0013	0.00433
Chiou <i>et al.</i> , 2008	400 W	0.8 L	48.9 mg L <sup>-1</sup>	1.0 g L <sup>-1</sup>	0.004	0.004
Azevedo <i>et al.</i> , 2009	4 W	6 L	100 mg L <sup>-1</sup>	2.3 g L <sup>-1</sup>	0.0002	8.7 x 10 <sup>-5</sup>
Górska <i>et al.</i> , 2009	1000 W	25 mL	19.7 mg L <sup>-1</sup>	5 g L <sup>-1</sup>	0.025	0.0005