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Photocatalytic degradation and adsorption of 2-naphthol on suspended TiO_2 surface in a dynamic reactor

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Abstract

The photocatalytic oxidation of 2-naphthol has been investigated at room temperature in a dynamic photoreactor with system UV/O_2 (air) and aqueous suspension of titanium dioxide TiO_2 irradiated under a variety of conditions. The kinetics of disappearance of pollutant were affected by several operating parameters such as TiO_2 mass, concentration of the substrate and reaction pH. The experiments were measured by high performance liquid chromatography. A Langmuir–Hinshelwood model was found to be accurate for photocatalytic degradation and indicates that adsorption of the solute on the surface of semiconductor particles plays a role in photocatalytic reaction.

Keywords: Dynamic photoreactor; Photocatalysis; Titanium dioxide; 2-Naphthol; Adsorption

1. Introduction

Photochemical advanced oxidation process (AOP), including photocatalysis, have been proposed in recent years as an attractive alternative for the treatment of contaminated ground, surface, and wastewater containing nonbiodegradable organic compounds [1–5]. Nevertheless, the photocatalytic oxidation of pollutants in aqueous suspensions of semiconductor TiO_2 irradiated by near UV is considered the most promising for the remediation of contaminated waters [6–11].

In AOP, the hydroxyl radicals ($OH^{\bullet}$) are generated in solution and these are responsible for the oxidation and mineralization of the organic pollutants to water and carbon dioxide [12–14].

However, one important consideration in the TiO_2-photocatalyzed reactions is the adsorption of the organic compounds on the surface of catalyst particles. It has been suggested that preliminary adsorption is a prerequisite of highly efficient detoxification [15].

Our objective in this work is to study the influence of physicochemical parameters on the initial photodegradation rates of 2-naphthol by photocatalysis using a dynamic photoreactor and to understand the mode of adsorption on the TiO_2 surface.

It is interesting to note that the photocatalytic degradation of this pollutant in the presence of various illuminated solids was observed in laboratory experiments using a static photoreactor [16].

2. Experimental

2.1. Materials

All chemicals were reagent grade and were used without further treatment. 2-Naphthol was purchased by Fluka (>99% purity). The photocatalyst was TiO_2 "Degussa P-25", mainly anatase (80% anatase and 20% rutile), with a surface area of 50 m^2/g, a density of 3.85 g/cm^3, and an average particle size of 30 nm.

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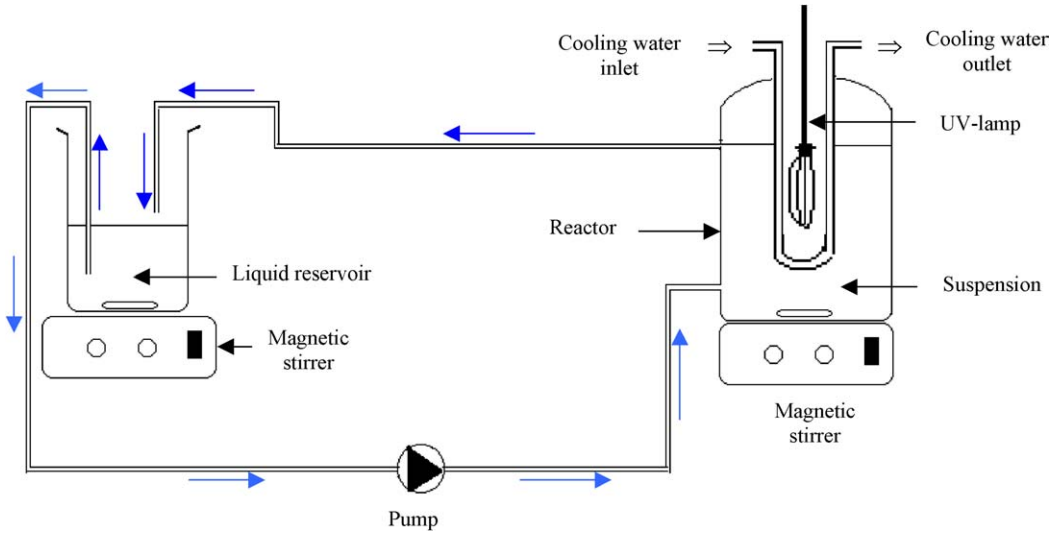

Fig. 1. Schematic diagram of photoreactor and experimental setup.

2.2. Procedure and analysis

The experiments were performed in dynamic flow photoreactor. A schematic diagram of the experimental setup, which is a basically batch recirculating system, is shown in Fig. 1. The photoreactor was cylindrical with volume 2 L and was made from quartz glass, which made possible the transfer of the irradiation. Irradiation was achieved by a high-pressure mercury lamp (Philips HPK 125 W) which was immersed in the glass tube. The UV lamp was equipped with a cooling water jacket system, and was positioned inside the inner part of the photoreactor containing an aqueous dispersion of 2-naphthol. A driver pump was used to recirculate the solution back to the liquid reservoir. The suspension was circulated at a flow rate of 240 mL/min and irradiated for 180 min.

The quantitative and qualitative analysis of the organic compounds in the samples was performed by HPLC (Jasco-type). The wavelength of detector was 280 nm. A reverse-phase column (length 25 cm; internal diameter 4.6 mm) ODS-2 Spherisorb (C-18) was used. The mobile phase was composed of acetonitrile (80%) and doubly distilled water (20%). The flow rate was 0.4 mL/min. The concentrations were determined after filtration of the suspension through Millipore filters (0.45 µm diameter).

3. Results and discussion

3.1. Kinetics of the photocatalytic disappearance of 2-naphthol

3.1.1. Comparison between direct photolysis and photocatalysis

Measurements were made on suspensions prepared by mixing 2 L solution of initial concentration of 2-naphthol (5×10^{-4} mol/L) at natural pH $\approx$ 6 and fixed amount of

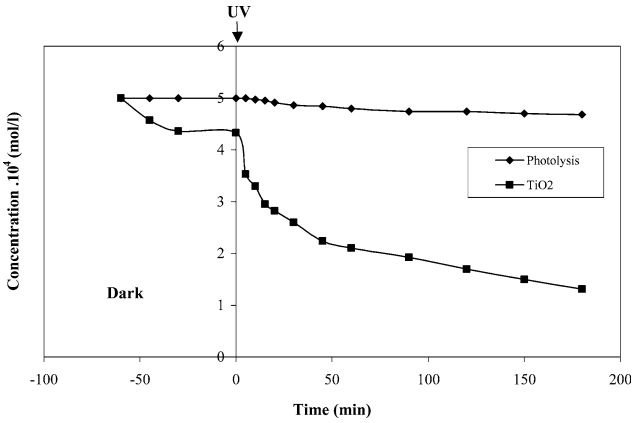

Fig. 2. Kinetics of 2-naphthol disappearance in absence and in presence of illuminated catalyst TiO_2.

TiO_2 (2 g). However, the role of adsorption on the photocatalytic degradation rate is still uncertain. Before irradiation, a period of adsorption in the dark of 1 h has been chosen from the above results of adsorption (Fig. 2). It can be observed first that the direct photolysis without semiconductors can be neglected with less than 4% of conversion within 3 h of illumination. In the presence of TiO_2, a rapid decomposition of pollutant occurs; it causes 80% degradation after 3 h of UV irradiation. These experiments show that the photocatalytic degradation in the presence of solid TiO_2 is more efficient than direct photolysis.

3.1.2. Effect of the mass of catalyst

The optimal catalyst concentrations reported in literature for TiO_2 "Degussa P-25" a range from 0.1 to 5 g/L depending on the nature of the compounds and the photoreactor geometry [17].

The effect of the amount of catalyst TiO_2 on the photodegradation rate was investigated. At a fixed pH and