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SOLAR PHOTOCATALYTIC TREATMENT OF PHENOL IN AQUEOUS SOLUTIONS

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Abstract

The photodegradation of aqueous solutions of phenol and intermediate products, hydroquinone and chatecol was investigated using a photo-reactor compound parabolic collector (CPC), sunlight and TiO₂ as catalyst. Photodegradation kinetics of the phenol has been explained in terms of the Langmuir-Hinshelwood kinetics models. The contaminants degradation was analyzed by means of a high performance liquid chromatography (HPLC) and total organic carbon (TOC) of solution was measured using TOC analyzer. The contaminants were degraded in more than 93% and the degree of mineralization of the contaminants was greater than 60%. [1-6]

Introduction

The main objective of the work is to evaluate the heliophotocatalytic degradation of aqueous solutions of phenol and some of their more important intermediate products, due to that these contaminants are found in the wastewater of several industries. In this study the degradation heliophotocatalytic of aqueous solutions of phenol with concentrations between 60-280 mg/l approximately, and of their intermediate products, chatecol and hydroquinone were evaluated. A study of the kinetics of degradation which is adjusted to the kinetics model of Langmuir-Hinshelwood (L-H) is done and finally, a comparison between the degradation of the pollutants employing solar energy and artificial energy is done.

Experimental methods

- Apparatus and Analysis

All of the following experiments were carried out in a photo-reactor compound parabolic collector (CPC) in pirex glass, this collector has been especially designer for solar chemical applications, operated in the batch and recirculation mode. The photo-reactor has a total volume of 2 liters of capacity of which 0.76 liters are irradiated, with a external diameter of 1 inch and a solar aluminum mirror type CPC, supported in a structure of iron, with an inclination of 30° north latitude. Samples solutions were continuously air bubbled and continuous recirculation of the solution, TiO₂ in suspension, using solar energy as a radiation source. Before each experimental run, the photo-reactor system was cleaned by pumping deionized water through it for about 15 min., as indicated by the optical densities of the water, this procedure allowed the removal of some residual compounds from previous runs. For preparation of standards Milli-Q water prepared with a Millipore System was used. All filtration were performed with filters from Millipore, cellulose of acetate, CHROMAFIL® CA-45/25, diameter of pore 0.45 µm and diameter of the filter 25 mm, syringe driven filter. Global UV(300-400 nm) irradiation in the solar photo-reactor was recorded with a radiometer

UV of the G5842 series, which includes photodiode and filter for UV. That way incident UV radiation could be evaluated as a function of time of day, cloudiness and other environmental variations [7-8]. In order to make the following of the photocatalytic treatment and to be able to evaluate the degradation of phenol and its intermediate species concentrations that appear during the reaction, in this case the hydroquinone and chatecol, were analyzed using a High Performance Liquid Chromatographer (HPLC-UV), VARIANT (With system of data acquisition through program Star Chromatography Workstation) with detector 9050 and pump 9010, with a lamp of deuterium and column C18 100-5, NUCLEOSIL® PROTEC I and the eluent was a mixture of acetonitrile (36%), water (60%) and acetic acid (4%). The flow rate was 0.8 ml/min and detection wavelength was 270. The following mineralization was made by means of Total Organics Carbon Analyzer (TOC-VCSH/CSN) Shimadzu.

Results and discussion

In the work the phenol concentrations were varied between 60- 280 mg/l approximately and the concentration of TiO_2 was of 0,5 g/l, stayed the pH constant in an approximated value of 5. Before beginning the illumination with solar energy, the solutions were left during 30 minutes under the dark, with the purpose of reaching the equilibrium of adsorption and desorption. In all the cases the irradiation was made with solar energy and the solution was recirculated during a determined time. In order to remove the catalyst after the treatment process cellulose of acetate filters were used. There is an important and quantifiable factor, that it is difficult to control, the solar radiation, which depends on the climatic conditions, therefore, is necessary to clarify that a constant irradiation for each one of the experiments cannot be guaranteed.

In fig.1, it is observed that for low initial phenol concentrations, the photodegradation process is greater. For example, 61% of phenol and 56% of the TOC have been degraded in a time of 7,5 hours when the initial phenol concentration is of 280 mg/l, whereas the 100% of phenol and 83% of the TOC have been degraded in he same time when the initial concentration is of 57 mg/l.

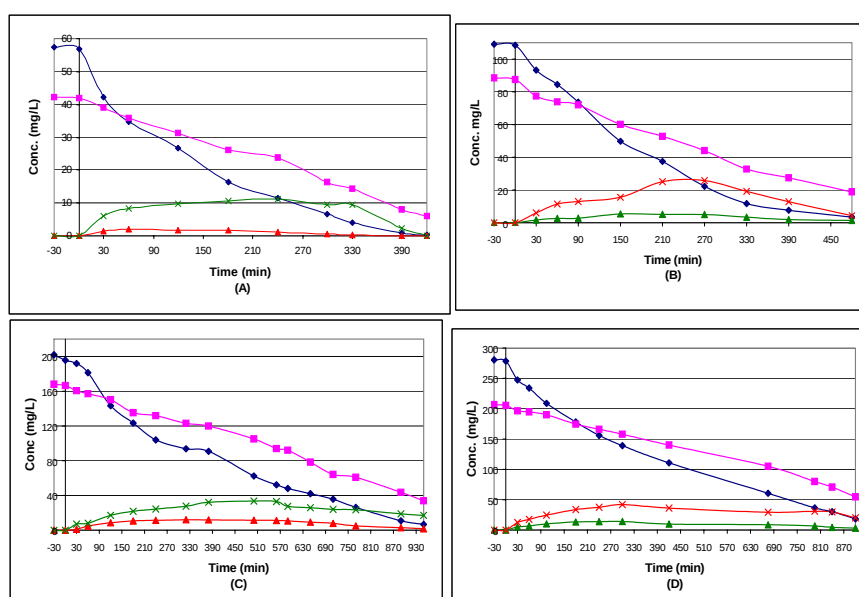


Fig. 1. Concentration profiles of phenol $\blacklozenge$ and intermediate species, chatecol $\blacktriangle$ and hydroquinone $\times$, TOC $\blacksquare$, varying the initial concentration of phenol, TiO_2 in suspension 0,5 g/l at an initial pH of 5.0. (a) 57 mg/l, (b) 109 mg/l, (c) 211 mg/l and 280 (d) mg/l.

Conclusions

The kinetics of photodegradation of phenol was explained in terms of the kinetics model of Langmuir-Hinshelwood (L-H), where the kinetic constants of the process were determined, for the use of the photo-reactor, which depend considerably on the geometry of the photo-reactor, type of irradiation, catalyst, among others. The polluting agents were degraded in more of 93% and the degree of mineralization was greater than 60% depending on the type of test. The constant of adsorption in the dark was determined and it was found that it is different from the calculated one from the kinetic model of L-H, because the photoreactive sites on the surface of the catalyst diminish because of the adsorption of the phenol and its intermediate species in their surface. The process of degradation of phenol and their intermediate species with solar and artificial energy was compared and it was found that the degradation process has a same behavior, nevertheless, the rate of degradation of phenol for the system with artificial energy is three times greater, this happened because the radiant flux is not constant during the test.

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