The Application of Photocatalytic Oxidation in Removing Pentachlorophenol from Contaminated Water

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Abstract:

The degradation of sodium salt of pentachlorophenol (PCPS) by photocatalysis with titanium dioxide (TiO_2) as the catalyst was investigated. The residual PCPS after photo-degradation was analyzed by high performance liquid chromatograph (HPLC) while the concentration of the chloride ion (Cl^-) was measured by ion chromotography. The results show that the degradation of PCPS by heterogeneous photocatalysis with UV/TiO_2 reaction was much faster and more complete compared to the rate of UV irradiation alone. The suitable dose of catalyst to degrade the [PCPS] with a concentration of 10-40 mg.L^{-1} was found to be as low as 0.05 g.L^{-1}. As the influent PCPS concentration increased to 60-80 mg.L^{-1}, the required TiO_2 dose doubled. The first order and Sips (combination of Langmuir – Hinshelwood kinetics) kinetics were used to predict the degradation rate of organic contaminants treated by illuminated TiO_2. The results showed that the Sips model fitted well with the experimental data. During the photocatalytic degradation of PCPS, the pH value reduced (from 8.1 to 3.5) with the reaction time while the concentration of Cl^- increased significantly. This finding indicates the decholorination and formation of intermediates during the oxidation process.

Keywords: Pentachlorophenol sodium (PCPS), photocatalysis, titanium dioxide (TiO_2)

Introduction

Organic herbicide runoff from farms into surface waters is a major concern due to the content of synthetic organic compounds (SOCs). Although their effects on humans have not been established, it is a potential carcinogen and may disrupt the production of normal hormones (1). Different destructive methods that efficiently eliminate the organic pollutants from aqueous solution have been employed, for example: chemical oxidation, incineration or degradation. The application of either of them will depend on the target compound, the concentration of the influent and desired effluent.

Oxidation is a chemical process that mineralises the constituents of organic pollutants and converts them into simple and relatively harmless molecules. The development of this process has led to a range of advanced oxidation processes (AOPs) that have demonstrated an effective means of water remediation as compared to the conventional technologies, such as adsorption, air stripping and biodegradation.

AOP with UV-light based processes in particular has attracted the attention of many researchers due to its dual benefits of both organic breakdown and detoxification of contaminated water. UV photolysis are based on the generation of hydroxyl radicals (·OH) that facilitate the oxidation of organics through the direct photolysis of strong oxidising agents such as hydrogen peroxide, ozone, sodium hypochlorite and Fenton's reagents. An excellent review on advanced oxidation using Fenton Reagent for degradation of organic contaminants is reported in the literature (2). This provides details on AOP.

A new initiative was then developed using semiconductors as the light-absorbing species to sensitize the photoconversion of toxic substrates to less toxic and harmless ones. Titanium dioxide is the most commonly used photocatalyst material due to its strong redox ability, chemical stability and availability at low cost. In the photo-oxidation process, hydroxyl radicals (·OH) are generated when catalyst (TiO_2) is illuminated by ultraviolet (UV) light. As a result, organic compounds are mineralized into CO_2, H_2O and inorganic constituents.

Compared to the Fenton, Fenton-like, and photo-Fenton reactions (Fe(II)/H_2O/UV), UV-assisted ozonation (O_3/UV), Direct UV photolysis (UV) and the O_3/UV systems, TiO_2 photocatalyst-related AOP can remove a wide range of pollutant due to adsorption. In

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