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Rapid photocatalytic decolorization of methylene blue using high photon flux UV/TiO_2/H_2O_2 process

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HIGHLIGHTS

- We study rapid decolorization using high UV photon flux UV/TiO_2/H_2O_2 process.
- 98% decolorization of 20 mg L^{-1} methylene blue could be achieved in 10 s.
- This process could reduce electrical energy consumption.
- H_2O_2 could increase light utilization efficiency as well as photonic efficiency.

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ABSTRACT

UV/TiO_2/H_2O_2 decolorization of methylene blue (MB) was studied under high UV photon flux irradiation; the UV photon flux in this work was ranging from 3.13×10^{-8} to 3.13×10^{-6} einstein cm^{-2} s^{-1}. It was shown that photodegradation using UV/TiO_2/H_2O_2 process was much more effective than UV/TiO_2 process. Under the optimal conditions of UV/TiO_2/H_2O_2 process, 98% decolorization of 20 mg L^{-1} MB could be achieved in 10 s. Kinetics of UV/TiO_2/H_2O_2 decolorization follows pseudo-first order with respect to the dye concentration. In UV/TiO_2 process, the photocatalytic rate constant increased with the square root of photon flux under high photon flux UV irradiation, and addition of H_2O_2 could turned the square root relationship closed to linear relationship. The apparent photonic efficiency under various experimental conditions have been calculated and the results also clarified that H_2O_2 could improve the light utilization efficiency of photocatalytic process. The electrical energy per order (E_{EO}) values showed that adding H_2O_2 could reduce energy consumption remarkably. Besides, effect of H_2O_2 concentration, effect of MB initial concentration and TOC removal were also studied.

1. Introduction

The process of photocatalytic oxidation has shown high efficiency in the degradation of various organic and inorganic pollutants. The excitation of photocatalyst generated highly reactive electron–hole pairs that in turn produce highly potent radicals to oxidize organic and inorganic pollutants. It offers a high potential as a new technology processes for environmental remediation [1,2]. UV light photon flux is one of the most important parameters in photocatalytic process, and our previous study has shown that high UV intensity can effectively compensate for the low reaction rate of photocatalytic process [3]. However, high photon flux in photocatalytic process would also lead lower light energy utilization efficiency because of electron–hole recombination [4].

The recombination of holes and electrons has been regarded as an unfavorable or limiting process in photocatalysis using titanium dioxide suspensions [5]. Especially in high photon flux irradiation photocatalytic process, the recombination increases dramatically and competes with hole–electron separation, thereby causing lower effect on the reaction rate and energy utilization efficiency [6]. For this reason many studies have focused on reducing the effect of the recombination of charges by applying different techniques, including the electrochemical method [7], surface modification of photocatalyst [8], and adding an external electron acceptor such as hydrogen peroxide [9]. Hydrogen peroxide is considered to be environmentally friendly as it is composed only of oxygen and hydrogen atoms and it could promote the photocatalysis in two ways. Firstly, the reduction of H_2O_2 at the conduction band would produce hydroxyl radicals. Secondly, the direct self photocleavage by UV irradiation would also produce hydroxyl radicals [10]. Many research groups have investigated the effect of hydrogen peroxide on photocatalytic process [9–11], however, there was seldom

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