Chapter 8
Photocatalysis (TiO_2/ Solar) in Water and Wastewater Treatment

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ABSTRACT

Advanced oxidation processes (AOPs) have gained growing importance for the removal of organic pollutants from water. Heterogeneous photocatalysis has been rapidly expanding for water treatment. This approach has economic and sustainability advantages compared with other processes. The main advantage of this process is its capability to gain complete oxidation or mineralization of organic contaminants at conditions of near ambient temperature and pressure. This chapter aims to review the mechanism involved in this process, characteristics of semiconductor photocatalyst, difference between suspended and immobilized photocatalyst system, comparison between the use of natural sunlight and commercial lamp, also the reactor involved. Potential advantages and limitations, as well as the application of photocatalysis in water and wastewater are also discussed.

INTRODUCTION

Water scarcity is strongly connected to the problem of water quality. Drastic urban development has deteriorated the quality of water and in some cases, made it unsafe for consumption (Naddeo et al., 2013). Due to continuous population growth, urbanization and industrialization, increasing water demands are stressing the existing water resources (Hashim et al., 2013). Over the last few decades, the occurrence of micro-pollutants in the environment has become a worldwide issue of increasing environmental concern. Micro-pollutants, also termed as emerging contaminants, consist of a vast and expanding array of anthropogenic as well as natural substances. Micro-pollutants are the thousands of inorganic and organic trace pollutants occurring at nano gram per liter (ng/L) to microgram per liter (μg/L) level of

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concentration (Luo et al., 2014). Micro-pollutants may exert toxic effects, even at such low concentrations, particularly when present as mixtures.

Micro-pollutants originate from different sources such as agricultural, industrial and everyday uses, for instance, personal care products, pharmaceuticals, and cleaning agents (Metz & Ingold, 2014). Routine analytical determinations of these parameters are never carried out because samplings and analyses are complex as well as time and money consuming (Guidotti et al., 2000). The low concentration and diversity of micro-pollutants not only complicates the detection and analysis procedures, but also creates challenges for water and wastewater treatment processes. With current condition of the environment, generally, organic micro-pollutants have become the center of attention to be eliminated in water and wastewater. Focusing on these pollutants which are resistant to biodegradation, the use of an alternative chemical oxidation method that can destroy these recalcitrant compounds is a matter of great concern. Among them, Advanced Oxidation Processes (AOPs) might probably constitute the best option in the near future (Cheng et al., 2016).

Over the last few decades, AOPs have gained growing importance for the removal of organic pollutants from water. The main advantage of AOPs compared to other technologies is the capability to gain complete oxidation or mineralization of organic contaminants through a process that operates near ambient temperature and pressure (Matilainen and Sillanpää, 2010). Photocatalysis which is also another AOP, has been rapidly expanding for water and air treatments (Al-Rasheed, 2005). This approach has economic and sustainability advantages in comparison with other processes, which require high energy costs (Marin et al., 2011). The mechanism, influential factors, advantages, and application of this AOP process will be discussed comprehensively in the following section.

Photocatalysis can be classified as homogeneous or heterogeneous processes, depending on whether they occur in a single phase or they make use of a heterogeneous catalyst like metal supported catalysts, carbon materials, or semiconductors, such as TiO_2, ZnO, and CdS (Oliveira et al., 2014). Homogeneous process is characterized by chemical changes depending on the interactions between the chemical reagents and target compounds (Ribeiro et al., 2015). Photo-Fenton reaction is categorized as a homogeneous process because it occurs when a light source is present, hydrogen peroxide (H_2O_2) will decompose by ferric (Fe^{2+}) ions present in the aqueous phase and resulting in the formation of hydroxyl radicals (Chong et al., 2010).

Heterogeneous photocatalysis is a chemical oxidation process in which a metal oxide semiconductor immersed in water and irradiated by near UV light ($\lambda < 385$ nm) which then results in the formation of free hydroxyl radicals (Umar and Aziz, 2013). The basic principle of semiconductor photocatalysis relies on the formation of an electron-hole pair upon the absorption of a photon with energy equal or bigger than the semiconductor band gap (Robertson et al., 2012). These two highly reactive entities are involved in a series of reductive and oxidative reactions on the semiconductor's surface (Chong et al., 2010).

MECHANISM OF PHOTOCATALYSIS

In the photocatalytic oxidation process, organic pollutants are destroyed in the presence of TiO_2 photocatalyst, an energetic light source, and an oxidizing agent such as oxygen and air. The electronic structure of a semiconductor plays a key role in this process. Figure 1 shows the schematic diagram illustrating the mechanism of a TiO_2-based photocatalysis. A semiconductor consists of the valence band and the conduction band. The energy difference between these two levels is said to be the band gap energy (E_g).

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