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Bimodal N-doped P25-TiO_2/AC composite: Preparation, characterization, physical stability, and synergistic adsorptive-solar photocatalytic removal of sulfamethazine

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ABSTRACT

A novel nitrogen-doped P25-TiO_2 of bimodal structure with activated carbon supported (N-P25-TiO_2/AC) was synthesized via the modified sol–gel techniques. Besides adding urea as N-source, the N-doping could also be induced through calcination under mixed NH_3/N_2 atmosphere. The composite was characterized using XRD, porosimetry, UV–vis spectrophotometry, FTIR, XPS, SEM/EDX and TEM. The physical stability of the composite was examined through ultrasonication disruption, and the composite exhibited good physical stability. The synergistic effects of the adsorption-solar photocatalysis of sulfamethazine (SMZ) as exhibited by the composites were examined. The best performing bimodal composite was N-P25-TiO_2 (25 + 10)/AC, which comprised 25% of N-P25 and 10% N-TiO_2 (sol) by weight composition (wt%). The maximum adsorption capacity (S_{max}) for the N-P25-TiO_2 (25 + 10)/AC, at pH 3.0, 6.0 and 10.0 was 183 ± 3, 194 ± 3, and 103 ± 2 mg g^{-1}, respectively. The effects of the total loading of N-doped titania, sol–gel synthesis technique, weight distribution of N-P25 and N-TiO_2 (sol), composite dosage, light wavelength spectrum and solution pH on the photocatalytic degradation (PCD) of SMZ were investigated. The N-P25-TiO_2 (25 + 10)/AC composite exhibited enhanced PCD efficiency under solar irradiation with a pseudo first-order rate constant (k_{app}) of 0.48 h^{-1}, as compared to other types of bimodal composites because its higher N-P25 content led to a greater photocatalytic activity.

1. Introduction

Heterogeneous photocatalysis is one of the proven technologies for removing various recalcitrant aqueous organic pollutants. In particular, titania (TiO_2) is the leading photocatalyst due to its remarkable photocatalytic activity upon excited by UV irradiation, chemical and biological stability, low toxicity, inexpensiveness, and commercial availability [1]. However, for practical application of titania in water treatment, two major issues need to be overcome, namely (i) the separation of titania from the product water, and (ii) the weak photoresponsiveness of bare titania under visible-light irradiation. To overcome the first limitation, activated carbon (AC) can be employed as the support of titania because it: (a) has an excellent affinity for various organic contaminants, (b) is widely used for water and wastewater treatment, (c) is readily available commercially with a wide range of properties suitable for various specific applications, and (d) has been reported to improve photonic efficiency for the supported TiO_2 by prolonging the charge (e^-/h^+) separation [2]. To overcome the second limitation, titania can be doped with nitrogen as previous researchers have shown that nitrogen-doped TiO_2 exhibited greater visible-light photoresponsiveness [3,4]. Thus, the impetus for applying photocatalysis in water reclamation is to develop a novel photocatalytic composite which can potentially present four major advantages: (a) removing various recalcitrant organic pollutants, (b) minimizing chemical consumption, (c) lowering the carbon footprint, and (d) producing zero waste stream.

In recent years, many works have been reported by various researchers on the subject of titania coated on activated carbon (TiO_2/AC) [5–7]. Generally, the commercial titania (e.g. Degussa P25, Hombikat TiO_2, Ishihara TiO_2, Millenium TiO_2) are well known photocatalysts which exhibit good photocatalytic activity. In recent years, synthesis involving the integration of titania (sol) and commercial titania has been attempted because of the potential for enhanced photocatalytic performances or photoeletrochemical applications [8,9]. Since the commercial titania Degussa P25 is the most widely used photocatalyst which exhibits remarkable photocatalytic activity under UV irradiation, it possibly offers enhanced photocatalytic activity after integration into the TiO_2/AC composite. Nevertheless, it is imperative to further increase the

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