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Original Research Paper

Intensified photocatalytic degradation of 2, 4–dicholorophenoxyacetic acid using size-controlled silver nanoparticles: Effect of pre-synthesis extraction

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ABSTRACT

In this study, ultrafine silver (Ag) nanoparticles were synthesised in *Orthosiphon stamineus* (OS) extract via facile electrochemical method. Different pre–synthesis extraction methods, namely ultrasonic assisted extraction hydro–distillation (UAE–HD) and classical aqueous extraction (AE) were used and compared. UAE–HD attained the highest total phenolic compounds at 8563.90 mg/kg. The Ag nanoparticles prepared via pre–synthesis extraction of UAE–HD (Ag_{UAE-HD}) and classical AE (Ag_{AE}) gave ultrafine sizes of 2 nm and 15 nm, respectively. It was suggested from the characterisation results that the phenolic compounds present in the OS extract had a significant role in the capping and stabilisation of Ag nanoparticles. Moreover, it was also demonstrated that the size of the Ag nanoparticles could simply be altered by varying the amount of total phenolic content (TPC) using different pre–synthesis extraction methods prior to the synthesis of Ag. Next, the photocatalytic activity of the Ag nanoparticles was tested towards the degradation of 2, 4–dicholorophenoxyacetic acid (2,4–D) herbicide. The synthesised Ag nanoparticles also showed outstanding photocatalytic activity with maximum degradation efficiency of up to 99.78% at pH 3, 0.01 g L^{-1} of catalyst dosage and 10 mg L^{-1} of 2, 4-D concentration. High amount of TPC contributed to the low energy band–gap (E_g) of Ag_{UAE-HD} catalyst and significantly inhibited the electron-hole recombination as well as enhanced the photocatalytic activity. The figures of merit based on electric energy consumption (E_{EO}) indicate that less energy was consumed during the degradation of 2,4–D in the presence of Ag_{UAE-HD} compared with other catalysts. Therefore, it could be concluded that Ag_{UAE-HD} is a promising material for high photocatalytic degradation efficiency of 2,4–D under optimal condition.

1. Introduction

In recent years, the development of modern industries has resulted in a large-scale development of the agrochemical industry. Among the numerous agrochemicals in use today, 2, 4-dichlorophenoxyacetic acid (2, 4-D) is a pollutant that is commonly found in the soil and groundwater near agricultural areas, causing potential threats toward humans and the ecosystem [1]. Thus, various types of treatment processes were developed for the removal of the 2, 4-D herbicide from the environment, including chemical precipitation, activated sludge, flotation, ion-exchange, and membrane filtration. However, these techniques have several drawbacks including secondary pollutant, high energy cost, and intensive energy requirement [2]. Photocatalytic degradation process by using photocatalysts is an effective method for organic removal due to low operation cost and is considered to be a convenient and successful method to treat wastewater containing organic pollutants [3–6].

Metal nanoparticles such as silver, gold, copper, platinum, and palladium have gained high scientific interest as photocatalysts in photocatalytic degradation due to their unique properties which arises from their large surface area to volume ratio which is comparable to bulk materials [7–11]. In addition, metal nanoparticles also have an excellent ability in absorbing visible light due to the surface plasmon resonance (SPR) effect [12]. Among them, silver (Ag) nanoparticles have drawn a lot of attention due to their high catalytic activity in catalysis, pharmaceutical, antimicrobial and

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