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Photodegradation of 2-chlorophenol over ZnO/KCC-1: Reaction optimization by response surface methodology

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ABSTRACT

Removing 2-chlorophenol (2CP) from water is an imperative task due to its toxicity. Various methods have been introduced for 2CP removal, and photocatalytic degradation is one of the best alternative solutions due to its effectiveness and simple process. This study focused on the potential of ZnO/KCC-1 as an effective photocatalyst for 2CP elimination from aqueous solutions. ZnO/KCC-1 was prepared by impregnating a commercial ZnO precursor into the synthesized KCC-1. The Zn/KCC-1 was characterized using TEM, FESEM, XRD, FTIR, and PL. The TEM and FESEM analyses confirmed the catalyst's fibrous structure with good ZnO dispersion. The XRD results demonstrated the amorphous silica structure with the presence of ZnO, while the FTIR analysis confirmed the formation of a strong Si-O-Zn bond. The PL analysis revealed a slower recombination rate of electrons and holes during the reaction, thus enhancing the degradation rate efficiently. The analysis via response surface methodology (RSM) over independent variables of initial concentration (X_1), catalyst dosage (X_2), and pH (X_3) revealed that X_2 was the most essential variable, while X_1 was the least significant variable. The ideal parameter for 2CP degradation was achieved at X_1 = 10 mg/L, X_2 = 2 g/L, and X_3 = 10 with photodegradation efficiency (Y) of 90.62 % (predicted) and 88.93 % (experimental). This research revealed that ZnO/KCC-1 had a great prospect for photocatalytic degradation of 2CP from an aqueous solution.

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1. Introduction

2-chlorophenol (2CP) with the formula of $C_6H_4Cl(OH)$ is an isomeric monochloride derivative of phenol and is widely used in various industries such as pharmaceuticals, petroleum refining, domestic preservatives, herbicides, pesticides, and textile industries. It is one of the most abundant organic contaminants in wastewater, and the treatment of wastewater containing 2CP has become an important task for both parties in the environmental and health sectors owing to its toxicity, mutagenicity, cytotoxicity, genotoxicity, and carcinogenic behaviour [1]. Despite the toxicity, the treatment of wastewater containing 2CP is becoming an important issue because of its low concentration limits, as low as 0.1 to 1.0 mg/L [2]. Therefore, removing 2CP from water sources and wastewater has attracted extensive attention, and various wastewater technologies have significantly evolved.

Among available wastewater treatment technologies, the photodegradation process has attracted extensive attention due to its environmental safety, overall pollutant degradation, no secondary emission, and fast catalyst oxidation [3]. The ZnO nanoparticle is one of the catalysts that has gained much attention owing to its availability, wide band gap energy, high photosensitivity, and excellent thermal stability [4]. However, ZnO tends to agglomerate leading to poor degradation activity due to the less available active sites [5]. Recently, researchers have utilized silica (SiO_2) as support material to avoid ZnO agglomeration. In addition, a new family of mesoporous silica nanospheres (KCC-1) or also known as synthesized dendritic fibrous nano-silica (DFNS), has now gained significant attention due to its potential for photocatalytic degradation [6]. This is mostly due to its remarkable physical qualities, which include a large surface area, excellent thermal and mechanical sta-

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