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THE 13TH INTERNATIONAL INNOVATION, INVENTION & DESIGN COMPETITION 2024

EXTENDED ABSTRACTS

e-BOOK

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PHOTOCATALYTIC DEGRADATION OF OFLOXACIN ANTIBIOTIC USING g-C_3N_4/ZnO FOR WASTEWATER TREATMENT

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ABSTRACT

In recent decades, the healthcare sector has made significant advances in increasing global reliance on antibiotics. It has also raised concerns about the possibility of antibiotics causing environmental and biotoxicity problems. Ofloxacin (OFL) is a fluoroquinolone antibiotic used to treat gastrointestinal, urinary, respiratory, and skin infections. It has been found in aquatic environments, especially in pharmaceutical waste. Due to its high phytotoxicity, it poses an ecological risk to aquatic ecosystems and can promote the development of antibiotic-resistant bacteria. To completely remove the ofloxacin from the environment, effective methods are needed. Recently, photocatalysis has attracted much attention for its potential to effectively, economically, and environmentally friendly remove organic pollutants from wastewater. ZnO is known as a potential photocatalyst for the degradation of wastewater in the UV region. However, ZnO has limited light absorption within the UV region and exhibits fast recombination of electron-hole pairs, which reduces its efficiency. To overcome this issue, a g-C_3N_4/ZnO photocatalyst for organic pollutant degradation in wastewater was developed to extend the light absorption towards the visible region. This research aims to investigate the photocatalytic performance of g-C_3N_4/ZnO nanocomposites in the degradation of ofloxacin. The composite catalyst of g-C_3N_4/ZnO was prepared by mixing g-C_3N_4 and ZnO. The prepared catalysts were characterized for material properties investigation. As a result of the composite photocatalyst combining ZnO and g-C_3N_4, the degradation of ofloxacin is 11.5 times higher than pristine ZnO and double times higher than pristine g-C_3N_4.

Keywords: photocatalysis, degradation, ofloxacin, g-C_3N_4/ZnO

1. INTRODUCTION

The increasing use of pharmaceuticals in recent years has attracted researchers' attention due to their harmful impacts on the environment. They have been identified as the most common organic pollutants found in wastewater from various sources, such as hospitals, households, industries, and agricultural waste. Antibiotics contribute to a large proportion of the numerous pharmaceutical products consumed due to their widespread use in veterinary and human medicine for the treatment or prevention of bacterial diseases (Gupta et al., 2023; Meng et al., 2023). Ofloxacin (OFL) is a quinolone antibiotic known as an antibacterial agent used for the treatment of bacterial infections in body parts including the skin, kidney, soft tissue, respiratory tract, and urine tract. OFL is a third-generation fluoroquinolone antibiotic and cannot be completely metabolized by the human body, in which 20-80% of the undigested agent is excreted in pharmacologically active form. It has been reported that low concentrations of OFL can accumulate in water for prolonged periods. The fluoroquinolones that are present in wastewater can lead to the proliferation of drug-resistant bacteria through induction and selection. It can be harmful to human health and can potentially reduce the ability of the human immune system to fight those bacteria strains (Cai et al., 2023; Cipagauta-Díaz et al., 2022).

Various methods have been extensively explored for the removal of OFL such as adsorption, biodegradation, chlorination, precipitation and coagulation (Ding et al., 2023). However, most of the methods are unable to remove the organic pollutant completely and effectively. In recent years, photocatalysis has attracted attention for antibiotic degradation due to its high efficiency, excellent stability, and eco-friendliness compared to the conventional methods. Photocatalysis is an Advanced Oxidation Process (AOPs) which involves the degradation of pollutants in wastewater to eliminate the contaminants species by employing the production of radicals through a redox reaction. The radicals will degrade the pollutants and transform products into their mineral constituents or less toxic compounds.

ZnO is a metal oxide semiconductor that has good electron transfer ability, exhibits photostability and can generate holes for strong oxidation. Despite its numerous advantages, ZnO has certain limitations of poor photocatalytic response to visible light due to having a wide band gap (3.37 eV) and fast recombination of photogenerated electron-hole pairs. Graphitic carbon nitride (g-C_3N_4) is the most stable allotrope of carbon nitrides at ambient temperature and has received a lot of attention in recent years. The g-C_3N_4 is a metal-free n-type semiconductor polymer with a two-dimensional structure like graphite. In the visible spectral range, g-C_3N_4 has a band gap of 2.7 eV, corresponding to an optical wavelength of 460 nm, making it an excellent photocatalyst. In addition to being safe and non-toxic, g-C_3N_4 is highly stable and has a strong reduction ability, as well as being light active. In this study, the evaluation of the photocatalytic performance of g-C_3N_4/ZnO was investigated and it was found that the performance of the composite g-C_3N_4/ZnO is higher than pristine.

2. METHODOLOGY

The synthesis method for the preparation of ZnO catalyst is the sol-gel method which involves the dissolution of the starting material, zinc acetate dihydrate, in absolute ethanol. The solution was then stirred using a magnetic stirrer for an hour to make sure the solution completely dissolved and obtained a homogenous mixture. The ammonium hydroxide was then added to the solution to obtain pH 9. The mixture was then dried to obtain the ZnO precursor. The ZnO precursor was then annealed at 300°C for 24 hours. The g-C_3N_4 was prepared using thermal decomposition at 550 °C for 3 hours. The preparation of a composite catalyst of g-C_3N_4/ZnO was done by mixing g-C_3N_4 and then dissolved in deionized water and stirred to obtain a homogenous solution. The mixture solution was then filtered and dried in an oven. The dry powder was then ground into a very fine powder to obtain the final products, which were ready for characterization. The photocatalytic activity of the photocatalyst was evaluated by the determination of OFL degradation at each interval using the UV-Vis NIR spectrophotometer. The photocatalytic reactor is equipped with a 150-watt LED visible lamp as the light source to carry out the photocatalytic activity.

3. FINDINGS

Figure 1 represents the XRD patterns of ZnO, g-C_3N_4, and composite g-C_3N_4/ZnO. The phase structure was analyzed by the XRD Xpert Highscore Plus software. The XRD pattern of ZnO and g-C_3N_4 correspond to the ICDD references which indicate all the samples are pure and have no impurities. The XRD pattern of composite materials shows the appearance of ZnO and g-C_3N_4 peaks, which indicate the success of the composite materials.

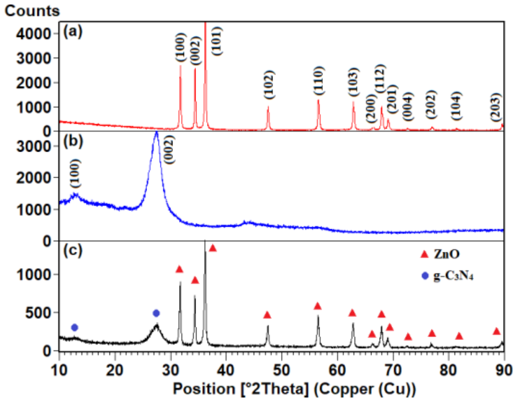

Figure 1 XRD patterns of (a) ZnO (b) g-C_3N_4 (c) g-C_3N_4/ZnO

Table 1 shows the values of total pore volume, pore diameter, and specific surface area of the sample from the N_2 sorption analysis as well as the percent degradation of OFL.

Table 1 Surface characteristics analysis and photocatalytic performance of photocatalysts

Sample	Total pore volume (cm^3g^{-1})	Mean pore diameter (nm)	Surface area (m^2g^{-1})	Types of pores	%Degradation
ZnO	0.009	54.10	7.22	Macroporous	5.5
g-C_3N_4	0.005	45.27	4.54	Mesoporous	47.9
g-C_3N_4/ZnO	0.010	46.14	8.30	Mesoporous	63.4

4. CONCLUSION

In this work, the g-C3N4/ZnO photocatalyst was successfully prepared via sol-gel, thermal decomposition, and followed by impregnation methods. The photocatalytic performance of OFL is 11.5 times higher than pristine ZnO and double times higher than pristine g-C_3N_4.

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