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Original Research Article

Photocatalytic Degradation of Amoxicillin Drug using ZnO/CdS Nanocomposite for Aqueous Solutions by using AOPs

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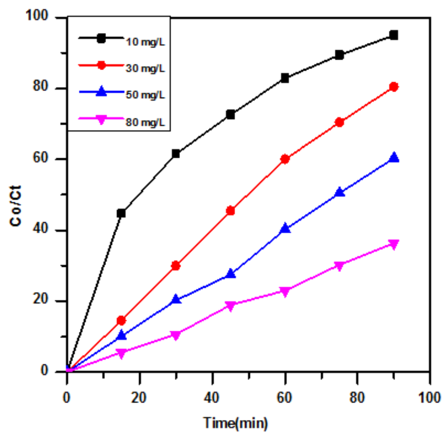
Hydrothermal

A B S T R A C T

The hydrothermal synthesis of ZnO/CdS nanocomposite studied for photocatalytic degradation of Amoxicillin (AMX) drug. The physical and chemical properties of the prepared ZnO/CdS were characterized using several analyses such as TEM, FE-SEM, TGA, and EDX. The photodegradation of Amoxicillin (AMX) drug was studied by employing UV-Vis light under several conditions in the presence of ZnO-CdS nanocomposite. Influence of several parameters such as AMX concentration (10-80 mg/L), mass of nanocomposite (0.1-0.4 g), and regeneration of ZnO-CdS nanocomposite was studied and optimized. All experiments were carried out under the most optimum conditions, which included a drug concentration of 30 mg/L, a light intensity of 1.2 mW/cm^2, and a solution pH of 6.8. The results showed that the photocatalytic efficiency rose with reducing concentration of AMX (95.99%-53.12%) when concentration increased from 10 to 80 mg/L. The photocatalytic degradation increased when the weight of the ZnO-CdS nanocomposite increased (44.43%-98.99%). It was observed that the photocatalytic efficiency of AMX was 80.86%-72.77.85% for the first to fourth cycles. This indicates the best stability of nanocomposites and could be potentially useful in practical batch degradation.

G R A P H I C A L A B S T R A C T



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Introduction

Pollution, especially environmental pollution resulting from the massive increases in population and industrialization, in particular the textile industries, has become one of the most prominent global issues since the late twentieth century [1]. Industrial dyes and medicines released into wastewater in general from various industrial sites contribute to organic pollution, causing continuous injury to marine organisms and fish and harming drinking water due to their toxic, carcinogenic nature [2-5]. Photo catalyst technology well-known on hetero-geneous catalysis' principles stands between one of the promising strategies to pacify ecological damage via complete mineralization of organic contaminants on expense of earth-abundant solar energy [6-10]. Advanced oxidation processes (AOPs), which include wastewater treatment methods including Fenton, ozonation, son-lysis, photo catalysis, UV photo catalysis, and wet air oxidation, constitute the foundation of environmental remediation science today [11,12]. These are defined as a group of chemical treatment methods used in environmental engineering intended to oxidize organic and occasionally inorganic contaminants from water and wastewater through interactions with hydroxyl radicals (OH). This term typically refers to a subset of chemical species that use UV, hydrogen peroxide, and ozone in the wastewater treatment field [13-15]. It has a great potential for several uses, like UV, photo catalysts, light emitters, piezoelectric transducers, surface acoustic wave devices, and optical waveguides [16-18]. ZnO is considered as one of the most important metal oxides used in eliminating pollutants and has many important applications such as transparent electrodes, gas sensors, variables, and other applications. In recent years, there has been renewed interest in their abilities to emit ultraviolet light [18-22]. Cadmium Sulfide (CdS) is a semi-conductor with a band gap of 2.42 eV and a maximum absorption peak of 514 nm wavelength which shows CdS can absorb visible light and UV light within a wavelength of ≤ 514 nm [23-26]. Amoxicillin (AMX), the medicine is an antibiotic that belongs to the amino acid penicillin family. AMX is used to treat pneumonia, middle ear, throat infections, skin infections, dental infections, and urinary tract infections. It is taken by injection or orally. Chemical formula $C_{16}H_{19}N_3O_5S$, molar mass 365.40 g·mol^{-1} and chemical stretcher appear in Figure 1 [27,28].

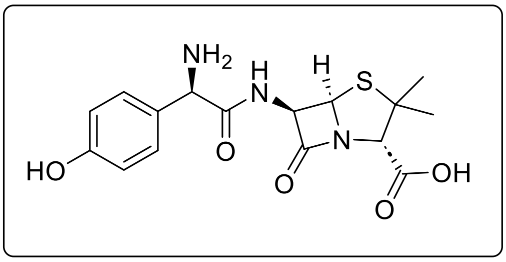


Figure 1. Chemical structure of (AMX) drug

Materials and Methods

All of the chemical reagents used (Sigma-Aldrich), cadmium acetate dehydrate ($Cd(CH_3COO)_2{\cdot}2H_2O$,99.5%), zinc oxide (ZnO NPs, 99.5%), reducing agents sodium sulfide (Na_2S, 95%), ethanol (CH_3CH_2OH, 98.5%), and sodium hydroxide NaOH, 99.5%).

Synthesis of ZnO/CdS nanocomposite

The ZnO-CdS composite nanostructures were synthesis by means of hydrothermal synthesis, where the suitable quantities of newly prepared ZnO NPs and cadmium acetate dehydrate were well dispersed in 10 mL of 1 g sodium sulfide (Na_2S) was added dropwise in to solution. The mixture was stirred magnetic for 1 h at 25 °C before being introduced to a hydrothermal system and heated to 160 °C for 24 h in an autoclave. Finally, the mixture washed with DW at a number of times and dried at 90 °C for 12 h.

Photocatalysis experiment

The photodegradation of AMX drug as a contaminant model was studied using photo catalysts. 200 mL of the solution drug with a 30 mg/L having photo catalyst was stirred for 10 min in the dark (adsorption) with 0.3 g of nanocomposite. The solution was irradiated via (UVA-meter) with 1.21 mw/cm^2 as visible light sources for 1 h, and sampled every 10 min during the photo catalytic degradation, at temperature constant 25 °C. The absorbance of drug solution was recorded *via* a spectrophotometer (λ_{max} = 272 nm), and photo catalytic (%PDE) of AMX was found utilizing Equation (1), as follows:

$$PDE\ (\%) = (C_0 - C_t)/C_0 \text{ x } 100 \qquad (1)$$

Where, PDE% is percentage of removal; C_0 is the initial concentration; and C_t is the residual concentration after a selective time of degradation of drug under studying.

Results and Discussion

FESEM

FE-SEM images of the prepared surfaces ZnO NPs and ZnO-CdS are displayed. The FESEM technique is used to detect the morphological characteristics of the samples as shown in Figure 2. Through the form Figure 2(a), an image of zinc oxide appeared in the form of spherical platforms with a very equal surface. However, some clumpy surface areas were observed [29,30].

While the surface shape after loading (CdS) on zinc oxide became rougher and more random in the form of scattered irregular balls in Figure 2b. TEM image was found to limit the morphology, particle size, and crystal structure and appear the average size at 200 nm of ZnO NPs and ZnO-CdS NPs, as shown in Figure 3. The surface morphology and crystal structure of ZnO and ZnO-CdS were explain [12]. In Figure 3(a), the surface of ZnO NPs is placed in a white spherical structure. In addition, after the process of loading CdS on ZnO NPs, a black spherical structure formed evidence of loading CdS on the surface of zinc oxide nanoparticle, as illustrated in Figure 3(b).

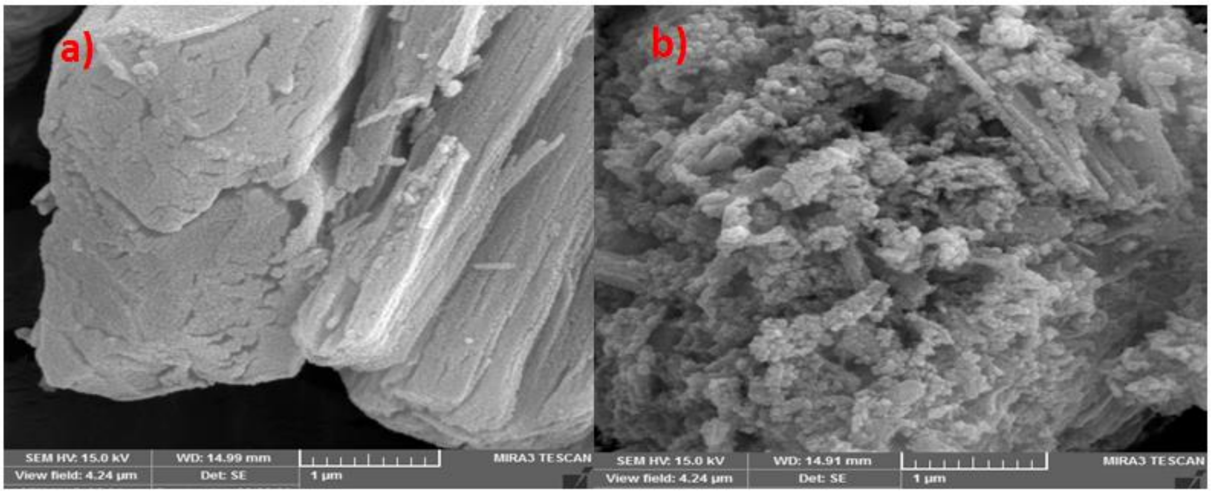


Figure 2. FESEM image of a) ZnO NPs and b) ZnO-Cds NPs

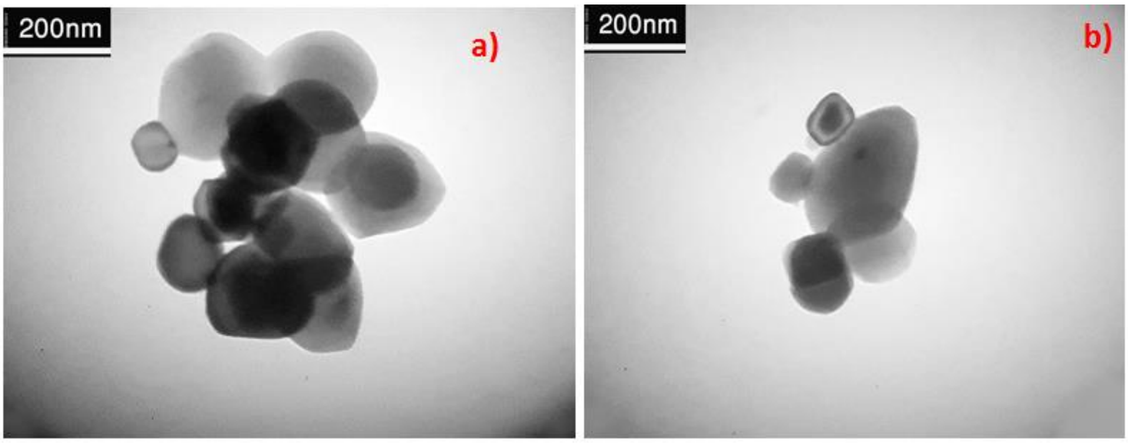


Figure 3. TEM image of a) ZnO NPs and b) ZnO-CdS NPS

Thermogravimetric TGA technique was used to surface ZnO-CdS NPs in a temperature range of 50-800 °C with an in-lattice heat of 10 °C/min, under flowing nitrogen at 200 mL/min g. A graph of the weight loss (%) versus temperature was demonstrated to determine the thermal stability and surface decomposition properties of ZnO-CdS NPs. The analysis revealed no significant weight loss, indicating the excellent thermal stability of the prepared ZnO-CdS NPs as shown in Figure 4(b). EDX technique use to determination of all elements in nanoparticles like C, O, Zn, and Cd, which indicates the presence of Cd onto nanoparticles [31-33], as shown in Figure 4(a).

Effect of Amoxicillin (AMX) drug concentration on photocatalytic activity

The impact of Amoxicillin (AMX) drug concentration under UV light utilized from 10-80 mg/L is found by weight of ZnO-CdS NPs about 0.3 g, pH solution 6.5, light intensity 1.2 mW/cm^2, and at 25 °C.

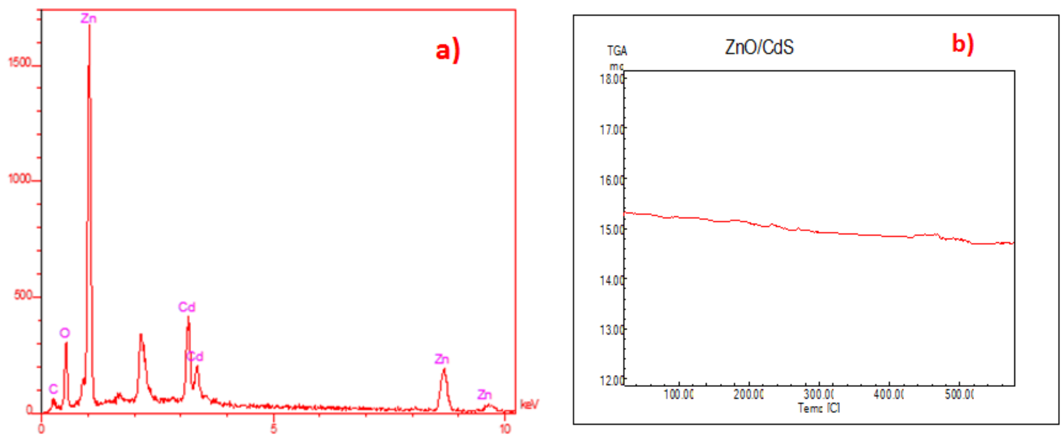
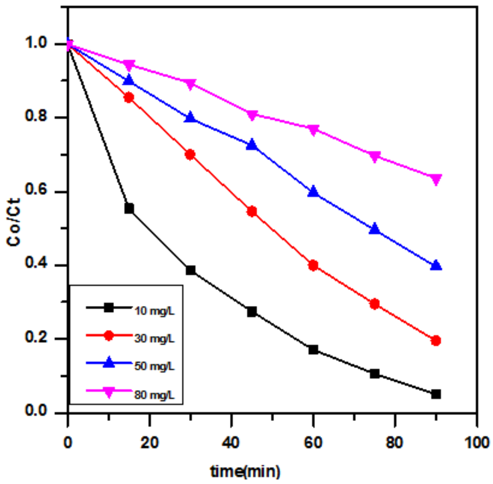


Figure 4. a) EDX technique of ZnO-CdS NPs, and b) Thermogravimetric TGA technique ZnO-CdS nanocomposite



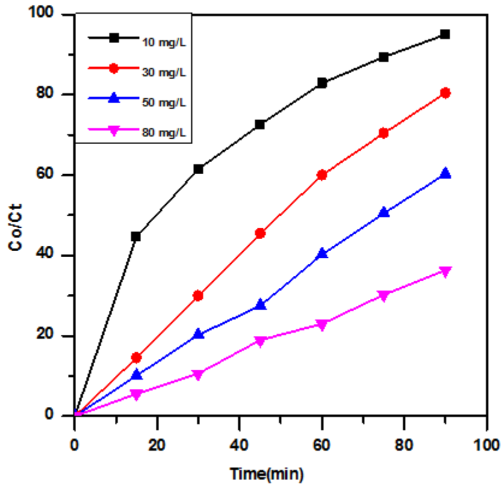


Figure 5. Photo catalytic degradation of several AMX drug concentrations

The AMX drug concentration is a limiting factor in maximum of elimination drug, especially in photo catalytic activity, as AMX drug concentration rises, it prevents the penetration of light irradiation in to the medium, thus AMX drug photo catalytic activity would be reduced remarkably, it means that when AMX drug concentration increases, the drug photocatalytic activity is decreased, as shown in Figure 5 [34,35]. The photo efficiency degradation of AMX drug decreases with increasing the concentration of AMX drug from (94.55% to 36.45%) when the concentration of AMX drug increases (10-100 mg/L) [36].

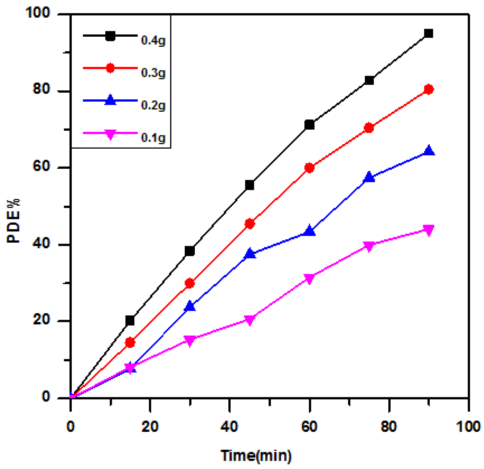
Effect of mass of ZnO-CdS NPS

Effect of quantities of ZnO-CdS NPS rang (0.1-0.4 g) on photocatalytic of AMX drug, The photocatalytic activity was done in the AMX drug concentration of 30 mg/L, time 60 min, and at 25 °C, as shown in Figure 6. The adsorbent dose impacts on elimination of 30 mg/L AMX drug. The increase mass of ZnO-CdS NPS about (0.1-0.4 g), the photocatalytic efficiency PDE% incensement of [14.6-80.88 %] after 60 min [37,38]. The results revealed that number of active sites of surface increases with increasing weight of ZnO-CdS NPs and equilibrium occurs between the numbers of photons absorbed by the catalyst and the absorbed AMX drug represents the photocatalytic degradation of quantity of ZnO-CdS NPs [39], as depicted in Figure 6.

Regeneration and reactivation of ZnO-CdS NPs

To reduce the cost-effective *via* utilizing an ecologically friendly surface that is simply prepared from obtainable and cheap materials, so it can be utilized in excess of once to eliminate contaminants because of the surface's high efficiency and active sites that can be re-activated. The prepared surface ZnO-CdS NPs has the photocatalytic efficiency of AMX drug within experimental conditions. The recyclability of ZnO-CdS NPs was examined for four cycles, as displayed in Figure 7 [15,40].

The ZnO-CdS NPs was washed several times in distilled water until the contaminant was removed from the surface. Based on the results, the photo catalysis gradually decreases after each cycle until all the surface active sites are saturated with the contaminant so that they cannot be removed and activated again. It was observed that the photocatalytic activity of the AMX drug was 80.86%, 78.9%, 76.9%, 74.6%, and 72.2%. This means that the surface can be used to remove pollutants with its advantage of reactivation and reduced economic cost [15,32].



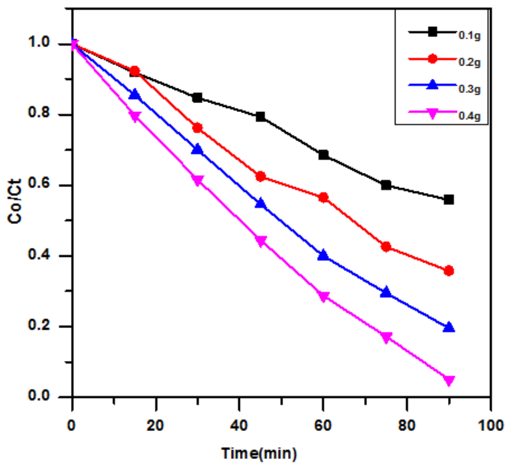


Figure 6. Photo catalytic degradation of AMX drug concentration at several weight of ZnO-CdS NPs

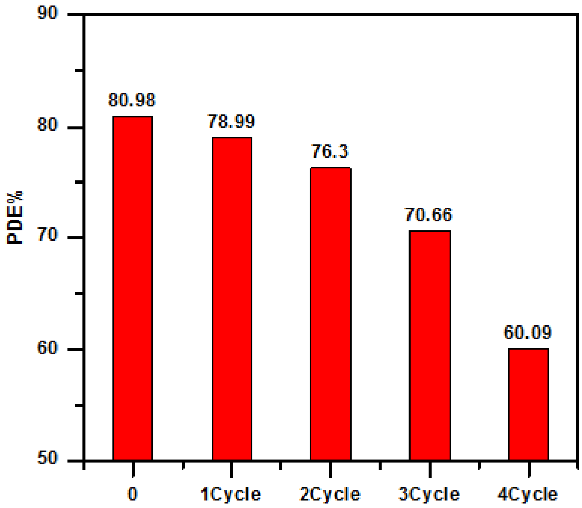


Figure 7. Regeneration and reactivation of ZnO-CdS NPs

Conclusion

Cadmium sulfide /zinc oxide nanocomposite synthesized *via* utilizing hydrothermal method as source of cadmium ions in found of cadmium acetate and Zinc oxide as showed high activity for photocatalytic activity of AMX drug. The nanocomposite can be efficiently used for the removal of drug. The photocatalytic activity method increased with increase in nanocomposite dose but decreased with increasing concentration of drug. The best photocatalytic degradation of drug was done with 0.3 g/L of ZnO/CdS nanocomposite. Photo activity efficiency decreased with increase concentration of drug and the best efficiency was observed at 30 mg/L. The best photo activity of drug was 80.88% when irradiated solution of drug via the UVA light for 60 min.

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