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RESEARCH PAPER

Evaluation of Cadmium Oxide Nanoparticles' Antibacterial and Antifungal Potential

*Zainab Alag Hasan [1], Rashid Rahim Hateet [2] , and Abdulameer Abdullah Al-Musawi [1]**

[1] College of Nursing, University of Basrah, Basra, Iraq

[2] College of Nursing, University of Mesan, Mesan, Iraq

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ABSTRACT

Pathogenic microorganisms that are resistant to antibiotics have made it necessary to look for new antimicrobials. Nowadays, employing nanoparticles as therapeutic agents may be novel and promising. Cadmium Oxide (CdO) nanoparticles were found to have antibacterial efficacy against bacteria that tested negative for the gram stain, such as *Pseudomonas aeruginosa*, *Salmonella typhi*, *Morganella morganii*, *Klebsiella pneumoniae*, *Proteus vulgaris*, and *Serratia spp*. They were also shown to have antimicrobial activity against bacteria that were positive for the gram stain, including *Streptococcus, Staphylococcus aureus* (ATCC 25923) measured between (10.0 to 18.5) mm, while antifungal agents were evaluated on *Candida albicans* and *Candida kruzi* with inhibition zones of 10.0 and 10.5 mm. The well diffusion approach was used to measure the nanoparticles' activity. The evaluated CdO nanoparticles had a concentration range of 100 mg/ml, and the activity was assessed by measuring the zone of inhibition. The results of the qualitative test included the determination of the MIC and MBC values. In the MIC range of 0.078-0.52mg/ml, CdO nanoparticles demonstrated good efficacy. Staphylococcus aureus demonstrated the maximum activity (MIC 0.078 mg/ ml), whereas *E. coli* displayed low susceptibility (MIC 0.83 mg/ ml). The cadmium oxide nanoparticles were studied using scanning electron microscopy with EDAX analysis and X-ray diffraction.

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INTRODUCTION

According to [1], pathogenic microorganisms are a serious health problem since they result in a significant number of hospital admissions and fatalities each year. Antibiotic-resistant bacteria are developing alarmingly [2].

Antimicrobial modification is a desirable goal to stop the growth of resistant microorganisms. Microbial invasion can result in serious infection [3]. Therefore, a high-priority topic for study is the creation of new antimicrobial chemicals or modifying existing ones [4]. The creation of antimicrobial materials and surfaces for use in healthcare, food, biomedicine, and individual care applications is therefore of tremendous interest [3,5,6].

A wide range of fungi, bacteria, and viruses are sensitive to the biocidal activity of metal ion-based nanomaterials [7]. Organic antimicrobial substances have been utilized as bactericides and insecticides for a very long time. Due to their antibacterial capabilities, manufacturing process

* Corresponding Author Email: abdulameer.yaqoob@uobasrah.edu.iq

heat was lowered. On the other hand, inorganic compounds demonstrated good thermal stability and resistance to bacteria [8]. Since the simplest structures are nanoparticles (sizes: 1-100 nm), any bound atom with a structural radius smaller than 100 nm is regarded as a nanoparticle. Nanoparticles have characteristics that set them apart from bulk materials, including low melting temperatures, greater surface areas, distinctive optical qualities, mechanical strength, and distinctive magnetizations [9].

Such "nanoparticles," which are essentially smaller versions of contemporary particles and are formed of various metals, can be produced via nanotechnology [10,6]. Although nanoparticles are still in the research and development stage, progress indicates that they have a promising future, especially in computer and sensor applications [11].

Metal nanoparticles can perform a variety of tasks that are not possible in the bulk phase [12,13]. Due to their distinctive physicochemical characteristics, such as optical, catalytic, electrical, antibacterial activity, and magnetic capabilities, metal nanoparticles have received much research. Since bacteria are the lowest-level organisms in ecosystems and so enter the food chain, the impact of nanoparticles on them is crucial [14].

An essential property of cadmium oxide (CdO), an n-type II-VI semiconductor, is its low electrical resistivity, broadband gap, and excellent visual transmittance. Burning Cd in the air produces the brownish CdO that is seen. It can be converted to conductive oxides because it absorbs CO2 from the air and is insoluble in water. CdO has a direct band gap of 2.5 eV and an indirect band gap of 1.98 eV. It is possible to sterilize and get rid of industrial and environmental microorganisms by manufacturing efficient nanomaterials with high activity against specific bacteria. Therefore, a study of its antibacterial activity is required. We evaluated the antibacterial and antifungal properties of cadmium oxide nanoparticles in this study.

MATERIALS AND METHODS

Microbial culture

The bacterial pathogens used in the study were obtained in 2015 from AL-Sadder University Hospital's Bank Culture Collection in Maysan, Iraq. They consist of seven gram-negative bacteria, such as *P. aeruginosa* and *S. typhi*, *M. morganii*, *K. pneumoniae*, *Serratia* sp, *P. vulgaris*, and the reference isolate *Escherichia coli* (ATCC 25922), as well as seven gram-positive bacteria, such as *S. epidermidis*, *S. pneumonia*. Nutrient Agar (NA) was utilized to cultivate bacteria, while Sabouraud Dextrose Agar (SDA) slants were employed to

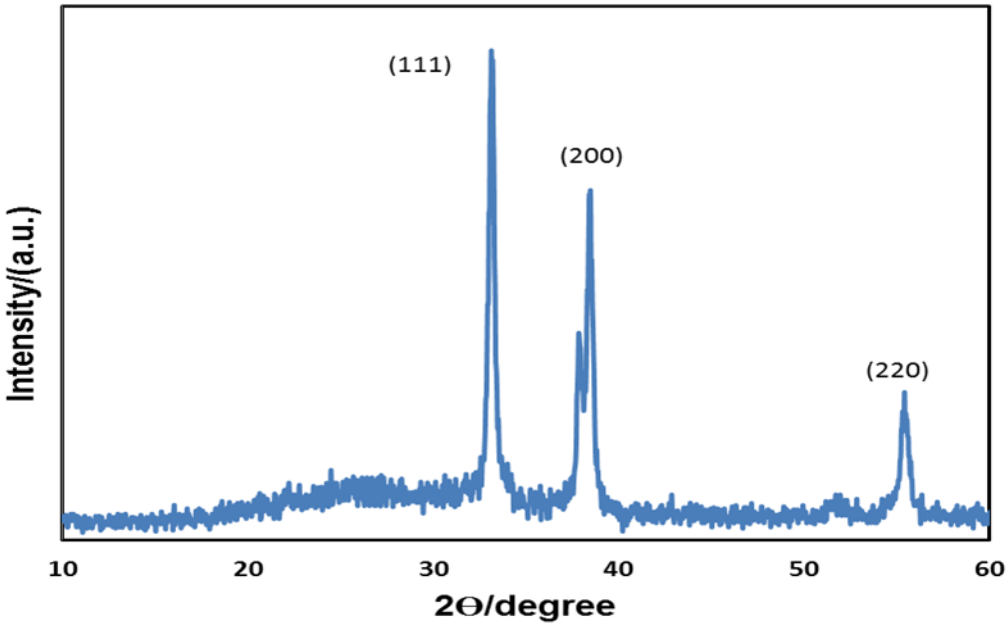

Fig. 1. XRD pattern of CdO nanoparticles.

cultivate yeast.

CdO nanoparticle preparation

Pure CdO was obtained by sol–gel spin coating. All chemicals were from Sigma Aldrich. Cadmium acetate dihydrate ($Cd(CH_3COO)_2$), methanol (CH_3OH), triethylamine ($N(CH_2CH_3)_3$) and glycerol ($C_3H_5(OH)_3$) were used as starting precursors with analytical purity. The CdO precursor consists of two solutions. The first was made by dissolving 4.0 g dehydrated cadmium acetate in 7 ml methanol. Then slowly add 0.25 ml of glycerin while stirring constantly. The second solution was prepared separately by dissolving 1 mL of triethylamine in 7 mL of methanol. This solution was slowly added to the first solution.The coating solution was applied to the slide and centrifuged at 1000 rpm for 2 minutes. The film was then dried in an oven at 350°C for 8 minutes to evaporate the solvent. This process was repeated three times before finally placing the sheet in a 450°C oven for 30 minutes and immersing in air, followed by slow oven cooling.

Characterization

The structure of the films was examined using X-ray diffraction (XRD) using the Philips PW-1710 apparatus with Cu-K radiation (0.15406 nm). The morphological profile of CdOnps was examined using scanning electron microscopy (SEM) with a Philips XL40. In order to investigate the composition, energy dispersive X-ray analysis (EDX) was employed. Using a collection of typical peaks for each element and their amounts, one can deduce their atomic composition.

CdO nanoparticles' antimicrobial activity

According to Rezaei-Zarchi et al. (2010), the agar disc diffusion test was used to determine the antibacterial activity of CdO-NPS. In order to evaluate the antimicrobial activity, Muller Hinton Agar (MHA) plates were prepared. An inoculum of bacteria, consisting of 100 µl, was spread out on plates. A 30-microliter volume of Cdo -nps, with a concentration of 50 mg/ml, was added to each well once it was prepared. The zone of inhibition was calculated using the Hi antibiotic zone scale during a 24-hour incubation of the MHA plates at 37°C. Following the completion of the experiment in three separate runs, the standard deviation was determined.

Minimum Inhibitory Concentrations

Each the MICs (Minimum Inhibitory

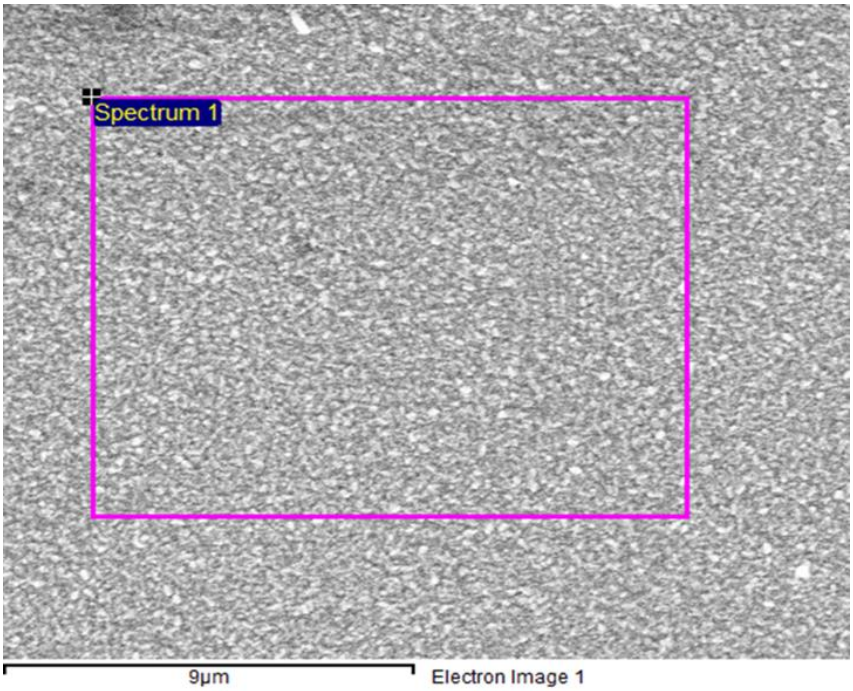

Fig. 2. SEM image pattern of CdO.

Concentration, Minimum Bactericidal Concentration, and Minimum Fungicidal Concentration) were determined using standard assay dilution [15]. This test was conducted on CdO-NPS as the lowest concentration did not show any turbidity after 24 hours of incubation compared to the control tubes . The bacterial inhibition test made use of both Müller-Hinton agar and Sabouraud's yeast with dextrose.

RESULTS AND DISCUSSION

The XRD spectrum of the cadmium oxide nanoparticles that were generated is shown in Fig. 1. The cubic surfaces-focused CdO data (JCPDS.Nr: 00-005-0640) perfectly matches all of the diffraction peaks.According to Cullity and Stock (2001), the crystallite size of the prepared nanoparticles was determined using the Scherrer relation D=(0.89 λ)/(β cosɢ). Here, λ is the wavelength of the X-ray source, and β is the angular full width at half-maximum (FWHM) of the XRD peak at the diffraction angle. Nanoparticles had an average size of 36 nm, according to XRD. The cadmium oxide nanoparticles' crystallites are spherical, and no peculiar or other impurity peaks were detected, according to scanning electron microscopy (SEM) pictures (Fig. 2) and an energy dispersive X-ray analysis (Fig. 3).

Cadmium oxide nanoparticles exhibited considerable antibacterial activity in seven Gram-positive zones of inhibition (11.5 mm-23 mm) and seven Gram-negative zones of inhibition (10 mm-18.5 mm), our result agree with [16] who have found antibacterial behavior of green synthesized nanoparticles against four separate bacterial species, "Pseudomonas aeruginosa, Klebsiella pneumoniae, Staphylococcus aureus, and Escherichia coli", using agar well diffusion. The findings revealed that the green synthesized CdOx nanoparticles demonstrated superior antibacterial activity in the field of inhibition (ZOI) against bacterial strains.

For two yeasts, the antifungal efficacy and zones of inhibition range from 10 to 10.5 mm, as shown in (Table 1). The size of the inhibitory zone varies across different types of bacteria. Evidence suggests that CdO may explain why Gram-negative bacteria are more likely to display the zone of inhibition compared to Gram-positive bacteria.

Gram-negative bacteria die as a result of nanoparticle damage to their cell membrane structure and a decrease in the function of certain

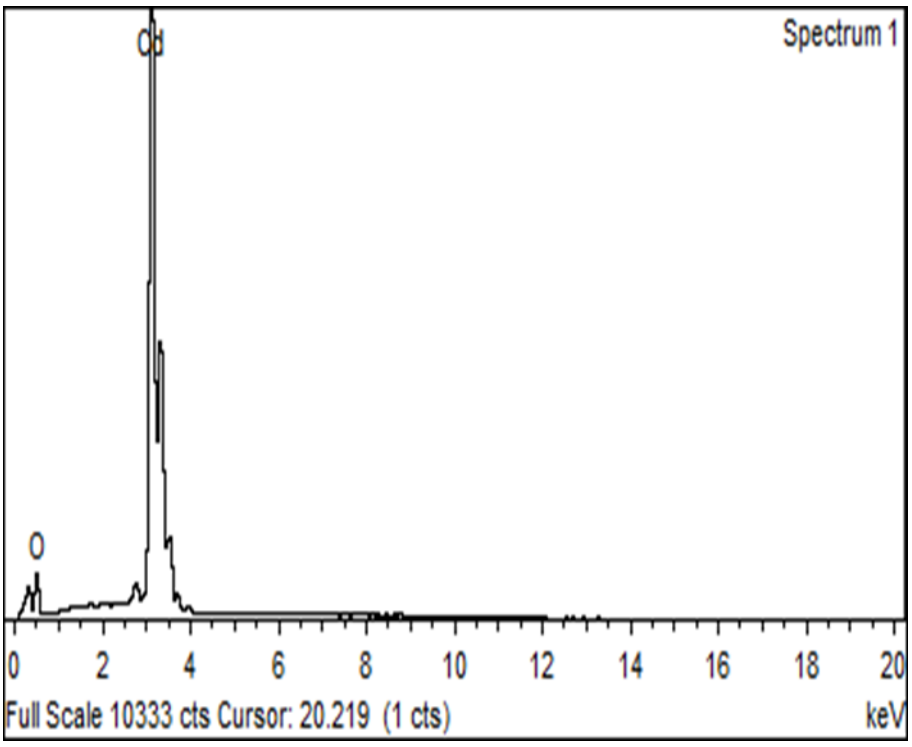

Fig. 3. EDX analysis of CdO nanoparticles.

Table 1. Antibacterial and antifungal activity of CdO nanoparticles.

Gram-Negative Bacteria	Z zones of inhibition (mm)	MIC(µg/ml)	MBC(µg/ml)
E. coli	23.0	25	50
Sal. Typhi	20.0	25	50
Ps.aeruginosa	11.5	100	200
K. pneumoniae	14.0	50	100
M. morganii	18.0	50	100
Serratia sp	12.0	100	200
P. vulgaris	15.5	50	100
Gram-Positive Bacteria			
S. aureus	18.5	50	100
S.epidermidis	10.0	100	200
Strep. Pneumoniae	16.5	25	50
Strep.pyogenes	10.0	100	200
E. faecalis	12.5	100	200
B. cereus	12.0	50	100
B.subtilis	18.0	50	100
Yeasts			MFC(µg/ml)
C.albicans	10.0	100	200
C.kruzi	10.5	50	100

Numbers are average of three replicates $P \leq 0.05$.

membrane enzymes [17,18].

Carefully crafted nanoparticles exhibit strong antibacterial action, as demonstrated by recent studies [19]. Table 1 shows that CdOnps exhibited low MIC values (25–200 g/mL), MBC values (50–200 g/mL), and MFC values (100–200 g/mL) against several bacterial species. Conventional wisdom held that the minimum inhibitory concentration (MIC) was the concentration at which microorganisms could not grow. Given that microorganisms have negative charges and metal nanoparticles have positive charges, an electromagnetic attraction between the two is likely to be the mechanism of action [20]. The thiol groups (-SH) on the surface of bacterial cells can be activated by ions produced by nanomaterials, leading to cell lysis (Table 1) [21,22].

CONCLUSION

The developed nanoparticles were characterized by XRD and SEM methods with EDAX measurements demonstrated potent antibacterial and antifungal activity against the microbes tested, demonstrating that the generated nanoparticles effectively inhibited their growth.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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