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Antimicrobial Activity of Zinc Oxides against Water Borne Pathogens

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Abstract

The disinfection of wastewater using Nano Particles (NPs) has become a focal area of research in water treatment. In this study, Zinc Oxide (ZnO) NPs were synthesized using the microwave heating crystallization technique and characterized using Transmission Electron Microscopy (TEM), Fourier Transforms Infrared (FTIR) spectroscopy, and X-Ray Diffraction (XRD). Qualitative good diffusion and quantitative Minimum Inhibitory Concentration (MIC) tests were conducted to determine the antimicrobial activity of ZnO NPs against selected waterborne pathogenic microbes. FTIR spectral studies confirmed that the binding of urea with Zn occurs through Zn-O stretching. XRD confirmed the crystallized identity in a hexagonal ZnO quartzite-type structure. The formation of inhibition zones and low MIC values in the antimicrobial analysis indicated the effective antimicrobial activity of zinc oxide nanoparticles against the test microorganisms. The application of metallic nanoparticles in water treatment could curb the spread of waterborne microbial diseases.

Keywords: Nanoparticles; Zinc oxide; Transmission electron microscopy; X-Ray diffraction; Qualitative well diffusion

Introduction

Due to their numerous applications in photo catalysis and antimicrobials, the ZnO-NPs are crucial for defense and water purification. ZnO-NPs have characteristics that set them apart from typical NPs. Additionally; these NPs are utilized in the production of sunblock creams, which protect the body from ultraviolet rays. ZnO-NPs are particularly well-suited for specialized biomedical applications because of their biocompatibility and non-toxicity. Metal oxide NPs play an important role in cosmetics and electronic equipment, among other consumer goods. ZnO-NPs are adaptable materials that possess distinct wettability, optoelectronic, and chemical properties. They are simple to make and used in a lot of different industries, like wastewater treatment [1]. Moreover, bimetallic nanoparticles have the greatest efficacy to demolish several water-borne zoonotic diseases. Leishmaniasis is a life-threatening disease in the tropical zone, and new methods for its treatment are gaining popularity. Numerous fabricated metal and oxide NPs are currently in use [2].

Discussion

The potency of ZnO nanoparticles

Much research endorses ZnONPs as the most beneficial metal nanoparticles, with minimal toxicity and excellent biocompatibility. The structural atom allocation mimics the most bioactive agent, emphasizing its pharmacological effectiveness against various ailments.

Antibacterial activity

As antibiotic resistance and bacterial infection rise, bacteria present a significant threat to human life. ZnO-NPs have been recognized as potent agents against MDR due to their exceptional antimicrobial properties and remarkable photo-oxidation and photo catalytic properties. ZnO-NPs' properties, such as the generation of ROS and zinc ions, are widely assumed to result in oxidative stress and DNA damage, as well as photo catalytic activity, which contributes to their antibacterial efficacy. The mechanism of ZnO NPs antimicrobial action is not well understood [3].

Antifungal activity

The antifungal properties of ZnO-NPs have been demonstrated in a number of published studies. The structure, size, and concentration of their compounds affect how effective they are against fungi. Bio fabricated ZnO-NPs antifungal efficacy against *Candida albicans* isolates was examined and it was discovered that Zn-NPs were more effective against drug-resistant *C. albicans* isolates, demonstrating ZnO-NPs antifungal efficacy. In addition, it was demonstrated that *G. mellonella* is shielded from *C. albicans* infection by prophylactic treatment with lower concentrations of ZnO-NPs. On clinical isolates of *Candida sp.*, the antifungal activity of a 2% ZnO-NP-based cold cream was higher than that of a 2% commercial antifungal cream. ZnO-NPs have been studied for their anti dermatophytic activity on *Trichophyton mentagrophytes* and *Trichophyton verrucosum*. ZnO-NPs have antifungal activity against both Aspergillus and Penicillium. In a similar vein, the Nano composite films of Soy Protein Isolate (SPI), Cinnamaldehyde (CIN), and ZnO-NPs displayed the highest antifungal activity among SPI, SPI-CIN, and SPI-ZnO-NPs films, being 1.56 times stronger than the SPI-ZnO film and 1.24 times stronger than the SPI-CIN film, respectively [3].

Efficacy of green synthesis of zinc nanoparticles

Natural methods have been developed for a "greener Union" of nanoparticles and have been shown to be more effective due to their slower energy, allowing for better focus product and control over the development and reliability of valuable compounds in nanostructure form that are economically, scientifically, and environmentally valuable. The green compound is getting better for things, real techniques are getting better, they are better for the environment, and they can be accurately estimated in large quantities. There is no good reason to use high pressures, energy, temperature, and synthesis. Zinc is caused by the presence of inhibitory organisms used in modern and

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clinical systems, as has been known for a long time [4, 5].

Water borne pathogens that is sensitive to ZnO-Nps

ZnO nanoparticles have been shown to be effective against both Gram-positive and Gram-negative bacteria, including major foodborne pathogens like *E. coli O157: Staphylococcus aureus*, Salmonella, *Listeria monocytogenes* [6].

Effect of Zinc nanoparticles on pathogen's biofilm

ZnO nanoparticles have been widely reported to have low toxicity to human cells for their antibacterial and antibiofilm activity against a wide range of microbes, including *Pseudomonas aeroginosa*, *Streptococcus pneumoniae*, *Listeria monocytogenes*, *Salmonella enteritidis*, and *E. coli*, as well as fungi like *Candida tropicalis* and Aspergillus. Due to their potent antimicrobial activity, these nanoparticles can inhibit microbial adhesion, proliferation, and biofilm formation. ZnO nanoparticles cause damage to bacterial cells by forming reactive oxygen species like $O^{-}\bullet$ HO_2, H_2O_2, $HO^{\bullet}$, and Zn^{2+} ions. However, various factors like UV illumination, size, shape, concentration, surface modifications, and surface defects affect their antibacterial activity. Among all metal oxide nanoparticles, it is widely reported that pure ZnO nanoparticles have significant antibacterial activity. Against Gram-positive *S. aureus* , *Bacillus subtilis*, and Gram-negative *E. coli*, *P. erogenous*, ZnO NPs displayed maximum antibacterial activity. They tried to find out if the size of NPs affects how effective they are against bacteria. The experiment revealed that ZnO nanoparticles with a size of approximately 18 nm had a maximum inhibition zone at a relatively low concentration. In a different experiment, they looked at the Minimum Bactericidal Concentration (MBC), and they found that ZnO killed *E. coli*, *S. aureus*, *P. erogenous*, and *B. subtilis* 72%, 80%, 88%, and 84% more effectively than CuO and Fe_2O_3 NPs. Beak and Wang et al. provided evidence to back up these findings who stated that ZnO was a nanoparticle with greater toxicity than other nanomaterial [7-9].

Mechanism of action on bacterial biofilm

The shape of nanoparticles has a significant impact on the release of Zn^{+2} ions. Due to their smaller surface area and high equilibrium solubility, spherical nanoparticles release more Zn^{+2} ions than rod-shaped ZnO. Zn^{+2} ions alter enzyme conformation, resulting in competitive or non-competitive reversible inhibition by distorting enzyme active sites. Zinc ions inhibit enzymes like glyceraldehydes 3 phosphate dehydrogenase, aldehyde dehydrogenase, and Protein Tyrosine Phosphatases (PTPs) primarily through interactions with the cysteine, aspartate, and histidine side chains of proteins or enzymes. Zn^{+2} is a common magnesium and aspartate inhibitor. The solubility of ZnO increases at pH values less than or equal to 6 above, which results in an increase in the number of Zn+2 ions [10].

Conclusion

In conclusion, ZnO nanoparticles had a lethal effect and remarkable antibacterial activity against most of the prominent water-borne bacteria. The direct interaction between ZnO nanoparticles and cell surfaces alters the permeability of membranes where nanoparticles enter and induce oxidative bacterial cells to be subjected to stress, which eventually causes cell death and growth inhibition.

Acknowledgement

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Conflict of Interest

None

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