



Antibacterial activity of ZnO nanoparticles against diverse bacterial strains

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Abstract

To control microbial infection, a number of novel tactics have been used. Increasingly, a new class of materials called metal oxide nanoparticles is being used. being acknowledged for its potential in health-related applications and research. According to recent investigations, metal oxides Nps that have been properly synthesized have strong antibacterial activity. Zinc oxide (ZnO) offers an array of exceptional advantages that make it a prized material across various fields. With its affordable cost, excellent gas sensing capabilities, and potent photocatalytic activity, ZnO proves to be a valuable asset in numerous applications. Its antimicrobial qualities ensure effective defense against harmful microorganisms, while the ability to create structures with unique optical features and act as a catalyst in small quantities adds to its versatility. Moreover, being non-toxic, ZnO is environmentally friendly and safe for use, making it an all-round remarkable substance with diverse practical uses.

Keywords: ZNO-NP, Resistance to Antibiotics, Metal Nanoparticles.

Introduction

In the twenty-first century, nanotechnology is a relatively new subject of study. Nanoparticles are atomic or molecular aggregates with sizes smaller than 100 nm (Bedi et al., 2015; Aabed and Mohammed., 2021). because of particular qualities Several fields use nanoparticles (NPs) in different ways. Zinc oxide nanoparticles are the most significant metal nanoparticles due to their widespread application in biomedicine, gas sensors, drug conveyance frameworks, biosensors, beauty care products, agribusiness, and wastewater management (Kaplan et al., 2003). With applications in science and technology aiming at creating novel materials at the Nano scale level, nanotechnology is an emerging, expanding discipline. Reducing the material's particle size in order to increase biocompatibility offers an effective and dependable application technique. In actuality, nanotechnology can overcome, size restrictions, which have the potential to alter how people view their use in science (Ennaoui et al.,1998).

Due to the effectiveness of numerous nanomaterials against different harmful microbes during the past few years, the enormous potential of nanotechnology has come to light. The use of metal particles, especially at the Nanoscale, to reduce bacterial infections is one way to combat bacterial medication resistance (Khameneh et al., 2015). It is believed that Nanoscale materials are special antibacterial specialists with a high region-to-volume proportion for forestalling the foundation of multidrug resistance in microbes. Many different kinds of nanomaterials include copper, iron, gold, magnesium, and zinc, alginate (Diab et al., 2016).

Chemistry of ZnO nanoparticles

The Zn atom in ZnO nanoparticles has an atomic number of 30 and is in the d-block of the periodic table, whereas the O atom is an atomic number of 8 and is in the p-block. ZnO is described as an inorganic material with an extensive variety of uses that is practical, strategic, promising, and adaptable inorganic material with a broad range of applications (Huh and Kwon., 2011). Another advantageous property of ZnO

nanoparticles for biomedical applications is their electrostatic properties. Most zinc oxide nanoparticles contain nonpartisan hydroxyl bunches joined to their surface, which is crucial to how they behave in terms of surface charge (Pandey et al., 2012). In an aqueous medium with a high pH, the chemisorbed protons (H⁺) depart the particle surface, leaving a negatively charged surface with partially attached oxygen atoms (ZnO). Protons from the surrounding environment are probably transported to the particle surface at lower pH levels, which resulted in a positive charge from ZnOH₂⁺ groups on the surface. According to the isoelectric point of 9–10, ZnO nanoparticles will have a large positive surface charge under normal conditions (Naqvi et al., 2012). indicates that ZnO nanoparticles will have a very positive surface charge when it comes to bodily functions. Due to their catalytic, electrical, optoelectronic, and photochemical capabilities, zinc oxide nanoparticles are widely used (Rai et al., 2012)

Properties of ZnO nanoparticles

As of yet, it is unknown exactly how nanoparticles work; they may have different effects depending on things like composition, surface modifications, characteristics, and concentration (Abdelraheem and Mohamed., 2021). ZnO-np, a metal oxide nanoparticle, is one of the more well-known nanoparticles. A polar inorganic substance is zinc oxide. It has many purposes, including antimicrobial, injury mending, UV sifting, high reactant, and photochemical movement, and is a white powder that is almost insoluble in water. This is due to a special combination of intriguing properties, including selective toxicity toward bacteria, minimal effects on human and animal cells, stability in a hydrogen plasma atmosphere, and low cost (Ozidal and Gurkok., 2022). the generation of reactive oxygen species, which kill bacteria, ZnO compromises the integrity of membranes (Gurkok et al., 2021) The creation of Zn²⁺ and hydrogen peroxide has also demonstrated a crucial function in the antibacterial action of nanoparticles (Baptista et al., 2018). Nevertheless, pathogenic bacteria can defend themselves from inhibitory substances by developing biofilms, ZnO nanoparticles' antibacterial and ant biofilm properties have recently been studied (Shanmuganathan et al., 2018).

Mechanisms of antibacterial properties of NPs

Nanoparticles apply their belongings by passing bacterial safeguards against medications and halting the arrangement of biofilms or other fundamental destructiveness-related processes. Nanoparticles can enter bacterial cell walls and layers and upset vital atomic cycle, NPs might show cooperative energy when used related to the assistance of the right anti-microbial in stopping the extending worldwide pestilence of anti-microbial obstruction. Moreover, Polymer-based nanoparticles empower the formation of a great many applications. remedial merchandise because of elements like expanded biocompatibility and biodegradability, When nanoparticles are embedded, stacked, or covered into different materials, antibacterial applications length from biomedical

and careful instruments to antimicrobial-engineered textiles (Slomberg., 2013). Many factors, including NPs' size, surface area, shape, net charge, and physicochemical characteristics, affect how effective they are against microbes (Pal et al., 2007). The surface-to-volume ratio dramatically rises when NP size lowers. Increased NP surface areas improve interactions with bacteria and have a significant impact on their antimicrobial properties. Positively charged metal NPs have reportedly been shown to connect more firmly to Bacterial surfaces that are negatively charged and exhibit stronger antibacterial properties. Because of their larger surface area, the spherical NPs have been demonstrated to have a stronger antibacterial impact (Leung et al., 2016). According to Slomberg et al., rod-shaped particles carry NO more efficiency than spherical particles and have better antibacterial effects across the biofilm (Lok et al., 2016). spherical or rod-shaped Ag NPs. Moreover, the kind of capping agent utilized and the medium's pH and ionic strength alter the antibacterial effect of NPs. The stabilizing effects of capping agents, which are deposited on the surface of NPs, are crucial in preventing NP aggregation and overgrowth. These substances impact the biological processes of NPs and some of their structural and physicochemical characteristics (Manzoor et al., 2021).

The mechanism underlying NPs' antibacterial abilities is still not completely understood. The particles can kill cells by several notable mechanisms, including

- (i) binding to bacteria and reducing the Permeability of cell membranes and respiration.
- (ii) releasing metal particles freed from the outer layer of NPs to cause toxicity.
- (iii) inducing oxidative damage by producing (ROS) reactive oxygen species.

The majority of the mechanisms are listed in Fig. 1 NPs' antimicrobial mechanisms. The main mechanism by which metal oxide NPs, such as ZnO and TiO₂, are believed to have Bactericidal properties is the production of ROS (Premanathan et al., 2011). Metallic ions can be produced by chemically oxidizing metals in aqueous solutions. NPs can produce more ions under aerobic conditions as opposed to bulk materials because of their increased surface-to-volume ratio. The ions that are discharged from the NPs' surface are crucial to action against bacteria. Because of their modest size at the Nano scale, NPs initially attach to the bacterial cell wall before passing through it and interacting with cellular membrane. With the ions they emit, they alter the cell membrane's structural makeup, compromising its integrity and raising its permeability. as well as the proton driving force, and impede oxidative phosphorylation (Aabed and Mohammed., 2021). ZnO-NPs were tried for their antibacterial movement against *Staphylococcus aureus* and *E. coli* and *Pseudomonas aeruginosa*. It was found that the antimicrobial impact was more prevalent in Gram-positive bacteria.

(Shakerimoghaddam et al., 2017). discovered that the impact of NPs on Gram-negative bacteria was noticeably stronger than on Gram-positive species. Studies that support the opposition are also available. Gram-positive *Staphylococcus aureus* had a stronger antimicrobial impact than Gram-negative *E. coli* and *Pseudomonas aeruginosa*, according to

Abdelraheem et al., (2021). *E. coli* and *Pseudomonas aeruginosa* were utilized to test ZnO-NPs for antimicrobial adequacy. as well as *Staphylococcus aureus* and the antimicrobial effect was viewed as more prominent in Gram-positive microscopic organisms. as Fig. 1.

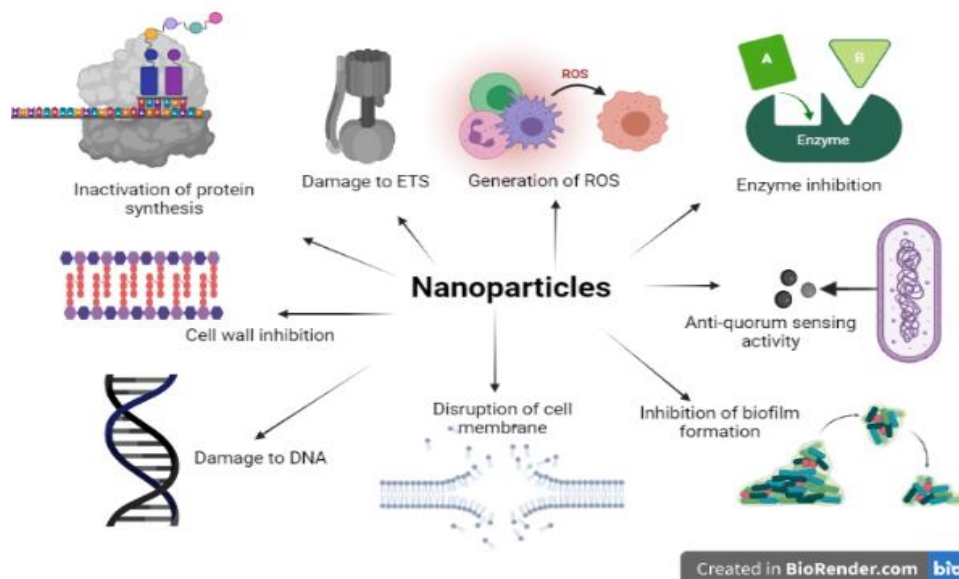


Fig. 1 NPs' antimicrobial mechanisms

The formation of hydrogen peroxide at the surface is assumed to be one of the mechanisms underlying ZnO nanoparticle antibacterial action and a more potent means of preventing bacterial growth. As bacteria's cell walls are negatively charged, oxygen and hydrogen peroxide have an antagonistic

relationship. As a result, the structure of cell proteins as well as the lipid on the cell membrane dissolves. When oxidized, zinc oxides suffer damage or can entirely disintegrate (Jasim et al., 2020) the Table 1. show concentration effect of ZNO in different type of bacteria.

Table 1. ZnO nanoparticles effect in different type of bacteria

Effect ZnO nanoparticles (MIC) µg/ml.	Bacteria type	Citation
8-128	<i>P. aeruginosa</i>	Abdelraheem et al., 2021
1250-5000	<i>E-coli</i>	Shakerimoghaddam et al., 2017
128–2048	<i>S.aureus</i>	Abdelraheem et al., 2021
625	<i>S. aureus (VRSA)</i>	Jasim et al., 2020
40	<i>K.pneumonia</i>	Reddy et al., 2014
3.9	<i>S. aureus</i>	Alekish et al., 2018
31.25	<i>E. coli</i>	
0.25	<i>E. coli</i> <i>A. baumannii</i>	Fadwa et al., 2021
0.390 to 500 ± 306.18	<i>Streptococcus mutans</i>	Almoudi et al., 2018

Conclusions

Antibiotic alternatives are available thanks to nanotechnology. Nanoparticles display a variety of characteristics to combat bacterial infections, including the suppression of biofilms and/or enhanced NP intracellular buildup. To manage the

virulence profile controlled by QS, Drug resistance and biofilm development, novel therapeutic drug candidates can be developed thanks to the nanotechnological intervention. As long as the right antibiotics are utilized in conjunction with nanoparticles to combat diseases, there is less chance of toxicity and the development of antibiotic resistance.

Nanoparticles and antibiotics can work together to combat dangerous microorganisms soon. Current developments in nanotechnology have made it possible to create novel nanomaterials with several antibacterial functions. When nanoparticles are loaded, they are coated, or embedded in various. They are used in a wide variety of products, including biomedical and surgical equipment as well as synthetic textiles with built-in antibacterial properties. Due to its qualities like improved biocompatibility and biodegradability, biopolymer-based nanomaterials facilitate the development of numerous pharmaceutical products. New uses for antibacterial nanoparticles will be revealed in light of the expanding field of nanomedicine research.

Conflict of Interest

The author hereby declares no conflict of interest.

Consent for publication

The author declares that the work has consent for publication.

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