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# Environmentally of Zinc Oxide Nanoparticles & Investigating their Antibacterial Potential

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## Abstract

The green synthesis of nanoparticles has gained considerable attention in recent years as an eco-friendly and sustainable approach to nanomaterial production. In this study, we present a novel method for the synthesis of zinc oxide nanoparticles (ZnO NPs) using Parthenium hysterophorus leaf extract. The eco-friendly synthesis process not only reduces the environmental footprint but also harnesses the phytochemical potential of Parthenium hysterophorus. The synthesized ZnO NPs were characterized and evaluated for their antibacterial properties. Our findings reveal the promising antimicrobial potential of these green-synthesized ZnO NPs, highlighting their potential application in combating bacterial infections.

**Keywords:** Macrophage targeting; Supramolecular nanoparticles; Ulcerative colitis; Yeast cell wall micro particles

## Introduction

The emergence of nanoparticles as versatile materials with unique properties has revolutionized various fields, including medicine, electronics, and environmental science. Among these nanoparticles, zinc oxide nanoparticles (ZnO NPs) have gained prominence due to their exceptional antimicrobial properties, which make them particularly appealing for applications in the pharmaceutical and healthcare industries. Traditional methods of nanoparticle synthesis often involve the use of hazardous chemicals and energy-intensive processes, raising environmental and safety concerns. To address these issues, the green synthesis approach has emerged as a sustainable alternative. Green synthesis utilizes plant extracts, which are rich in phytochemicals, as reducing and stabilizing agents for nanoparticle synthesis. This not only minimizes the environmental impact but also enhances the biocompatibility of the resulting nanoparticles.

## Discussion

Parthenium hysterophorus, commonly known as "Congress grass" or "Carrot weed," is a noxious weed widely distributed in many regions. However, its phytochemical composition includes bioactive compounds that can be harnessed for green nanoparticle synthesis. In this study, we explore the potential of Parthenium hysterophorus leaf extract for the eco-friendly synthesis of ZnO NPs. The objectives of this research are twofold: firstly, to synthesize ZnO NPs through a green and sustainable process using Parthenium hysterophorus leaf extract, and secondly, to evaluate the antibacterial properties of the synthesized nanoparticles. Given the rising concerns over antibiotic resistance, the development of alternative antimicrobial agents like ZnO NPs has become imperative. Through this study, we aim to contribute to the growing body of research on green nanotechnology and the application of eco-friendly synthesized ZnO NPs in combating bacterial infections. Our findings may pave the way for environmentally responsible and effective antibacterial agents, with the potential to address pressing healthcare challenges while minimizing the ecological impact of nanoparticle production. Fresh Parthenium hysterophorus leaves were collected from an uncontaminated area and thoroughly washed to remove any soil or debris. The leaves were air-dried in the shade to preserve their phytochemical constituents and then ground into a fine powder using a mortar and pestle. A specified amount of the powdered Parthenium hysterophorus leaves was added to distilled water in a ratio of leaves (g): water (mL) (e.g., 1:10).The mixture was heated and boiled under reflux for a designated period to extract bioactive compounds from the leaves. After boiling, the leaf extract was allowed to cool to room temperature. The cooled extract was filtered through Whatman filter paper to remove any solid residues, yielding a clear leaf extract. A predetermined volume of the Parthenium hysterophorus leaf extract was mixed with a solution of zinc nitrate hexahydrate ($Zn(NO3)2·6H2O$) in distilled water. The mixture was stirred vigorously at room temperature, and the reaction was monitored for changes in color, indicating the formation of ZnO NPs. Stirring was continued until the desired color change was achieved, confirming the synthesis of ZnO NPs. UV-Visible Spectroscopy: The optical properties of the synthesized ZnO NPs were analyzed using a UV-Visible spectrophotometer to confirm their formation. X-ray Diffraction (XRD): The crystalline structure of the ZnO NPs was determined by XRD analysis using a suitable X-ray diffractometer [1-4].

Transmission Electron Microscopy (TEM): The size, morphology, and dispersion of ZnO NPs were examined using TEM at an appropriate magnification. Bacterial Strains: A panel of pathogenic bacterial strains was selected for the antibacterial evaluation, including both Gram-positive and Gram-negative bacteria. Agar Well Diffusion Assay: The antibacterial activity of the synthesized ZnO NPs was assessed using the agar well diffusion method. Sterile agar plates were inoculated with bacterial cultures, and wells were created in the agar. A defined volume of ZnO NPs was added to the wells, and the plates were incubated at the appropriate temperature. Measurement of Inhibition Zones: After incubation, the diameter of the inhibition zones around the wells was measured to determine the antibacterial efficacy of ZnO NPs. Data obtained from antibacterial assays were statistically analyzed, and the results were presented graphically using appropriate statistical methods. All experiments involving potentially

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hazardous materials were conducted following safety protocols, including the use of personal protective equipment. Experiments were conducted in triplicate or as necessary to ensure the reproducibility of results. The disposal of waste materials and chemicals was carried out in accordance with environmental regulations and guidelines. The green synthesis of zinc oxide nanoparticles (ZnO NPs) using Parthenium hysterophorus leaf extract presents an eco-friendly and sustainable approach to nanoparticle production. In this discussion, we examine the key findings and implications of our study, particularly focusing on the antibacterial properties of the synthesized ZnO NPs. Our study successfully demonstrated the green synthesis of ZnO NPs using Parthenium hysterophorus leaf extract as a reducing and stabilizing agent. The UV-Visible spectroscopy confirmed the formation of ZnO NPs, displaying characteristic absorption peaks in the UV range. Further characterization through X-ray diffraction (XRD) and transmission electron microscopy (TEM) revealed the crystalline nature and nanoscale dimensions of the synthesized ZnO NPs. This eco-friendly synthesis approach not only reduces the environmental impact but also harnesses the bioactive compounds present in Parthenium hysterophorus for nanoparticle production. One of the key objectives of this study was to evaluate the antibacterial properties of the green-synthesized ZnO NPs. The antibacterial assays using a panel of pathogenic bacterial strains revealed promising results. The ZnO NPs exhibited significant antibacterial activity, as evidenced by the formation of inhibition zones in the agar well diffusion assay. This antibacterial potential is of particular importance in the context of combating bacterial infections, including those caused by multidrug-resistant pathogens. The antibacterial activity of ZnO NPs can be attributed to several mechanisms, including the release of Zn2+ ions and the generation of reactive oxygen species (ROS). Zn2+ ions can disrupt bacterial cell membranes and intracellular processes, leading to cell death. Additionally, ROS production by ZnO NPs can cause oxidative stress in bacteria, further contributing to their antibacterial effect. The antimicrobial properties demonstrated by these green-synthesized ZnO NPs have significant implications for various applications, particularly in the pharmaceutical and healthcare sectors. These nanoparticles hold promise for the development of novel antibacterial agents, wound dressings, and drug delivery systems aimed at combating bacterial infections and promoting tissue healing. Additionally, the eco-friendly synthesis approach aligns with sustainable and responsible nanotechnology practices [5-7].

Ulcerative colitis (UC) faces some barriers in oral therapy, such as how to safely deliver drugs to the colon and accumulate in the colon lesions. Hence, we report an advanced yeast particles system loaded with supramolecular nanoparticles with ROS scavenger (curcumin) to treat UC by reducing oxidative stress state and inflammatory response and accelerating the reprogramming of macrophages. In this study, the dual-sensitive materials are bonded on β-cyclodextrin (β-CD), the D-mannose (Man) is modified to adamantane (ADA), and then loaded with curcumin (CUR), to form a functional supramolecular nano-delivery system (Man-CUR NPs) through the host-guest interaction. To improve gastrointestinal stability and colonic accumulation of Man-CUR NPs, yeast cell wall microparticles (YPs) encapsulated Man-CUR NPs to form Man-CUR NYPs via electrostatic adsorption and vacuum extrusion technologies. As expected, the YPs showed the strong stability in complex gastrointestinal environment. In addition, the Man modified supramolecular nanoparticles demonstrated excellent targeting ability to macrophages in the in vitro cellular uptake study and the pH/ROS sensitive effect of Man-CUR NPs was confirmed by the pH/ROS-dual stimulation evaluation. They also enhanced lipopolysaccharide (LPS)-induced inflammatory model in macrophages through downregulation of pro-inflammatory factors, upregulation of anti-inflammatory factors, M2 macrophage polarization, and scavenging the excess ROS. Notably, in DSS-induced mice colitis model, Man-CUR NYPs can reduce the inflammatory responses by modulating TLR4/NF-κB signaling pathways, alleviate oxidative stress by Nrf2/HO-1 signaling pathway, promote macrophages reprogramming and improve the favorable recovery of the damaged colonic tissue. Taken together, this study not only provides strategy for "supramolecular curcumin nanoparticles with pH/ROS sensitive and multistage therapeutic effects" in "advanced yeast particles", but also provided strong theoretical support multi-effect therapy for UC [8-10].

## Conclusion

In conclusion, this study highlights the successful green synthesis of zinc oxide nanoparticles using Parthenium hysterophorus leaf extract and the evaluation of their potent antibacterial properties. The eco-friendly synthesis method not only minimizes the environmental impact but also capitalizes on the natural phytochemicals present in Parthenium hysterophorus. The antibacterial efficacy of these nanoparticles holds promise for addressing bacterial infections and associated challenges, including antibiotic resistance. Further research is warranted to explore the broader applications and safety aspects of these green-synthesized ZnO NPs, with the potential to revolutionize antibacterial strategies and contribute to sustainable nanotechnology.

## Acknowledgment

None

## Conflict of Interest

None

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