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Research Article

Plant-Mediated Synthesis of Zinc Oxide Nanoparticles: Advancements in Nanotechnology and Antimicrobial Research

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Abstract:
Zinc oxide nanoparticles have been made using Zinc Sulfate as a precursor and leaf extract from the Mentha Spearmint. The course of the reaction was probably monitored by the colour change of the resulting solution. The size of the nanoparticle was determined to be 31.78 nm, Ultraviolet (UV)-Visible Spectroscopy, powder X-ray diffraction techniques (XRD), Scanning Electron Microscope (SEM), and Transmission Electron Microscope (TEM). The microbiological activity of the generated ZnO-NPs is examined.

Key words: Spearmint leaves, Zinc Oxide Nanoparticles, Microbial effect.

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1. Introduction

In recent years, nanotechnology has emerged as a thriving field of study. Due to their small size, nanoparticles attract a lot of interest because of their distinctive surface to volume ratio. The study of designing, creating, and modifying the structure of particles with dimensions less than 100 nm is known as nanotechnology [1]. The production of different metal and metal oxide nanoparticles using environmentally safe and nontoxic methods has drawn a lot of attention in the research community in recent years. In order to create nanoparticles, green synthesis has used a number of biocompatible materials, including plant extracts, fungus, and algae, as capping and reducing agents [2,3,4]. Utilizing plant extracts provides an environmentally friendly way to regulate the variation in the particle's size, shape, and morphology [5]. Here, phytochemicals have been abundantly available from plant biodiversity. These phytochemicals include flavonoids and a wide variety of aliphatic or aromatic hydrocarbons [6]. Zinc oxide nanoparticles are among the most interesting materials that may be made using a green synthesis approach out of all the different metal and metal oxide nanoparticles. The production of metal oxide nanoparticles was attributed to the plant phytochemicals with antioxidant properties, such as terpenoids, flavonoids, and alkaloids, which were present in the aqueous leaf extract. The production of zinc oxide nanoparticles has garnered significant interest due to its many characteristics, including electrical conductivity, optical polarizability, magnetic, catalysis, and antibacterial activities.

Mentha Spearmint leaves were utilized in this work as a plant extract to create ZnO-nanoparticles. Due to its usage in treating digestive issues, headaches, fatigue, and anti-inflammatory and antibacterial properties, this plant is well known as a medicinal herb [7,8,9]. This study begins with a brief introduction to the natural-scale synthesis of zinc oxide nanoparticles. Zinc oxide nanoparticles' effectiveness depends on their size, physical qualities, and chemical composition [10].

2. Materials and methods

All of the chemicals used during this investigation, including sodium hydroxide and zinc sulfate, were provided by Sigma-Aldrich Chemicals in India and served as precursor materials.

The spearmint (Menthaspicata) was acquired from Shahaganj Aurangabad local market, spearmint leaves was cut and washed with tap water and distilled water to remove the dust particles and other possible contaminants, and then was dried at room temperature. They were finally crashed in mixer grinder and then the powder was Strainer Sieve.

2.1. Preparation of Leaf Extract (Mentha Spearmint)

The plant was extracted by combining 10g of dried spearmint leaves with 100 ml of double distillated water in a 250 ml beaker. For 1 hour, the container was put on an electric magnetic stirrer set at 90°C and 300 rpm. After cooling to room temperature, the solution was filtered using Whatman No.1 filter paper.

2.2. Synthesis of Zinc Oxide Nanoparticles

Green Synthesis of ZnO-NPs was carried out according to Chowdhury et al.[11] with minor modifications. For the synthesis of ZnO-NPs, 100 ml d/w of 0.1 M zinc sulfate heptahydrate ($ZnSO_4.7H_2O$) was stirred for 15 min, then 10 ml of leaf extract was added dropwise. The mixture was progressively stirred for 30 min at 50-60°C temperature using magnetic stirrer with speed of 2000 rpm. The pH of the solution was adjusted by adding 1 M NaOH drop by drop until the pH of the solution reached 10. The resultant mixture was stirred for 2 hrs, and the obtained precipitate. The solution was cooling at room temperature. After cooling down, the solution was centrifuged at 4000 rpm for 10 min. The precipitate was calcined for 2 hours at 400 ^{0}C in a muffle furnace. A fine white powder was acquired meticulously gathered, and preserved for future research.

3.0 Characterization:

3.1. X-ray Diffraction - (XRD)

The green fabrication of ZnO-NPs from Mentha Spearmint leaves was validated by physical characterization instruments. ZnO-NPs were crystallo graphically elucidated using X-ray diffraction (Brukar D8-Advanced Diffractometer).

3.2. Scanning Electron Microscope - (SEM)

ZnO-NPs morphological features, including size and topology, were analyzed using FE-SEM (Nova Nano-SEM NPEP303).

3.3. Energy-Dispersive X-ray Analysis - (EDX)

Energy dispersive X-ray spectroscopy (EDX, Bruker, XFlash 6I30) indicated the elemental composition and chemical purity.

3.4. UV-vis spectrum

The UV-Visible absorption spectrophotometer (JASCO UV V-750) was utilized to get the absorption spectrum. The steady synthesis of ZnO-NPs is shown by the distinctive absorption spectra. The 900–200 nm scanning range was used, and the speed was 400 nm/min.

3.5. Antimicrobial Activity

Biological activity of greenly produced ZnO-NPs was screened for antibacterial activity against two Gram-Positive Bacteria *viz. Staphylococcus aureus*and *Bacillus subtilis*, and Gram-Negative Bacteria *viz. Escherichia coli and Klebsiella pneuminiae*by disk diffusion assay[20]. Using Streptomycin (100 µs/disk) the reference standard for comparing the results. The Anti-bacterial activity was screened by using nutrient agar obtained from Hi-media. Composition (gL-1).Composition (gL-1)::Sodium chloride, 5.0; Beef extract 10.0; Peptone 10.0 (pH 7.2).

The Anti-fungal activity against *Aspergillus niger*by agar diffusion assay[21], Using Amphotericin B (100 units /disk) as the reference standard. The Antifungal activity is screened by using Sabouraud Agar Media and DMSO as control Solvent. The diameter of the Zone is measured by Vernier Calliper. The Anti-Bacterial and Anti-Fungal Activity of ZnO-NPs is shown in (Table No.1).

Table 1. Anti-bacterial and Anti-fungal Screening of ZnO-NPs

Compound	Microorganism	Strain Name&Strain reference	Zone Of Inhibition (ZOI) (mm)	Streptomycin	Amphotericin B
ZnO-NPs	Gram positive bacteria	S. aureus (NCIM 2079)	-	*25*	NA
		B. subtilis(NCIM 2250)	-	24	NA
	Gram negative bacteria	E. coli (ATCC 25922)	-	26	NA
		K. pneuminiae (NCIM 2719)	-	28	NA
	Fungi	A. Niger(ATCC 16404)	-	NA	NA

4. Results and Discussion

4.1. EDX and SEM

The existence of zinc and oxygen signals in zinc oxide nanoparticles made from mentha spearmint leaves was verified by EDX analysis (Table 2). The primary components in the sample were determined to be zinc (74.03%) and oxygen (24.32%) in this table.

Table 2: EDX Analysis of the Composition's Major Elements.

Element	% Weight	% Atomic
Zn	**74.03**	**42.18**
O	**24.32**	**56.63**
S	**0.38**	**0.44**
Cu	**1.27**	**0.74**

Utilizing the energy dispersive X-ray (EDX) technique, Figure 1 displays the fundamental composition of the produced ZnO-NPs. The presence of Zn and O in the sample is evident from this chart. Furthermore, the weak unassigned peaks that correspond to O, Cu and S might be caused by plant phytochemicals present in the sample.

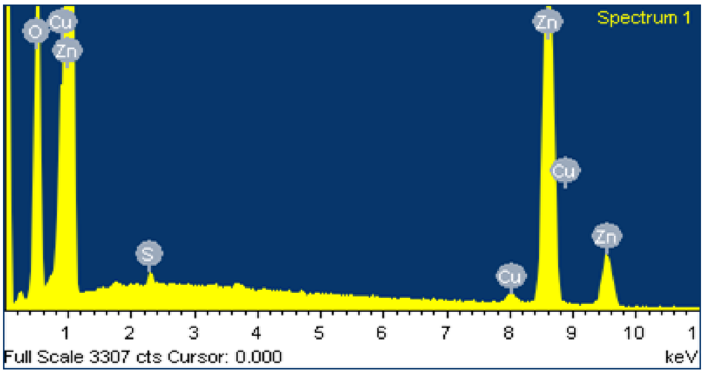

Figure 1 EDX micrographs of Zinc Oxide Nanoparticles

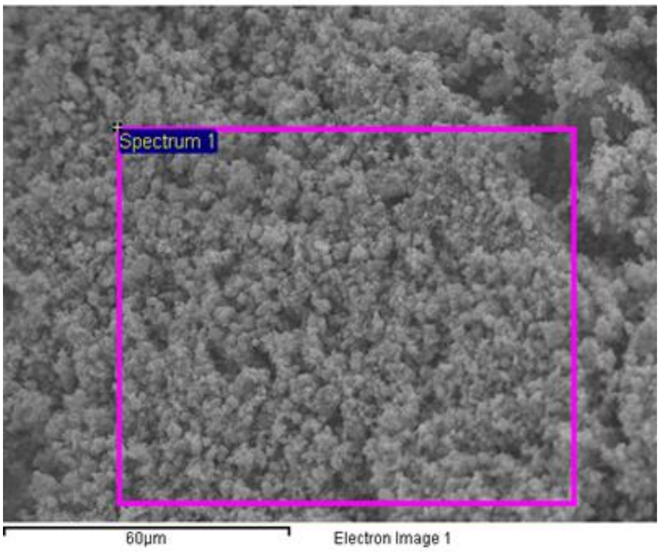

Figure 2 SEM micrographs of Zinc Oxide Nanoparticles

The surface morphological properties of the generated ZnO-NPs were investigated using a scanning electron microscope (SEM), Fig.2 show an aggregate of irregularly shaped nanoparticles. Furthermore, the particles have a hexagonal shape and show some agglomeration, which might be explained by the high energy and surface tension of ZnO nanoparticles. ZnO nanorods are widely employed in the electronics industry and represent 1D arrays [12]. The lowest surface energy of the nanorods facet primarily supports the formation and development of the ZnO nanorod [13].

4.2. X-ray Diffraction - (XRD)

Additionally, Fig. 3 shows the ZnO-nanoparticles X-ray diffraction spectrum. This pattern indicated that the zinc element that reflects the synthesis of zinc oxide nanoparticles from the spearmint leaves extract is the one that synthesizes the most zinc. The figure that shows the value of two in the 20–80 degree range which is connected to the hexagonal structure of zinc oxide has several interpretations. Reflections of crystalline plates (100), (002), (101), (102), and (110) were found at 29.52 degrees, 30.24 degrees, 35.55 degrees, 36.02 degrees, 48.93 degrees, and 62.51 degrees, respectively (JCPDS Card No. 36-1451),[14]. The Debye-Scherrer formula was used to measure the particle diameter, which ranged from 26.28 to 37.29 nanometers with an average of 31.78 nm.

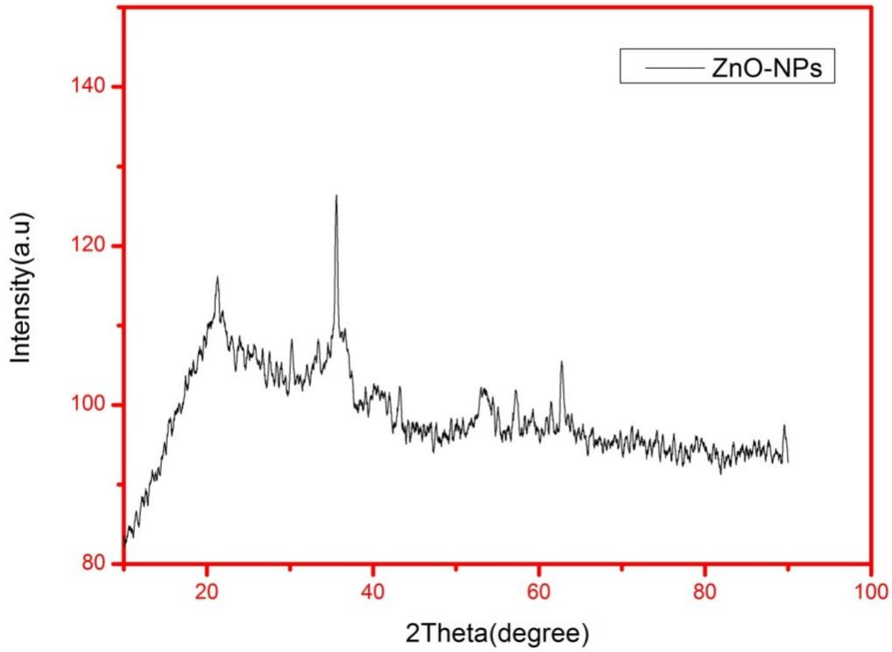

Figure 3XRD spectrum of ZnO-NPs

4.3. UV-vis spectrum

The optical properties of green synthesized ZnO-Nps were examined in this study using an absorbance spectrum from UV-vis characterization. Previous research showed that an absorption spectrum around 370 nm confirmed the successful synthesis of ZnO-Nps, and Fig. 4 showed an absorption peak at 370 nm that confirmed the presence of ZnO-Nps. Absorbance peak by ZnO [15,16,17] Nps primarily depends on particle size and shape, which is determined by a number of variables, including calcination temperature, pH value, precursor concentration, and others [18,19].

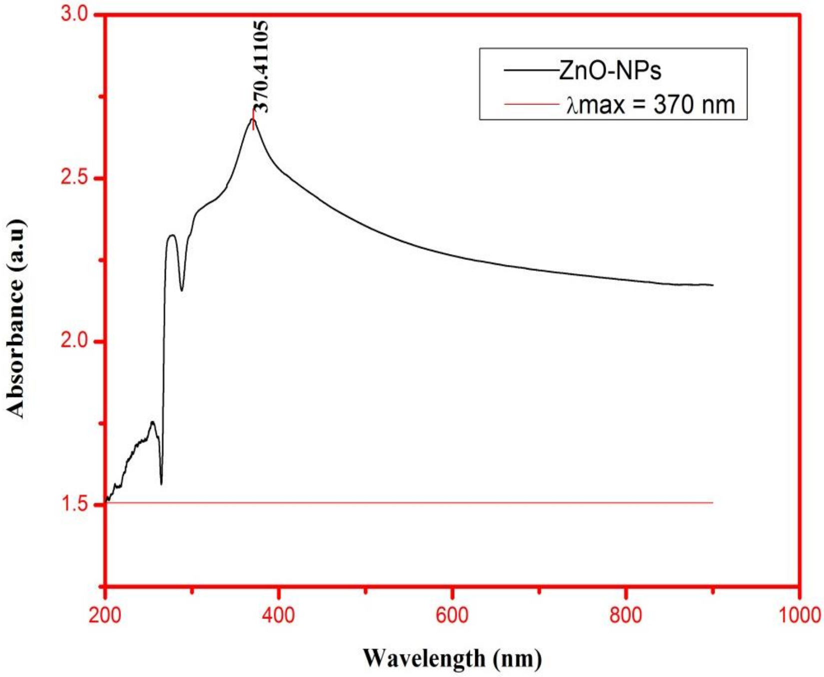

Figure 4UV-visspectrum of ZnO-NPs

4.4. Antimicrobial Activity

Screening of the biological activities of synthesized ZnO-NPs compounds revealed that, ZnO-NPs does not show Anti-bacterial and Anti-fungal activity against Gram Positive, Gram Negative bacteria and Fungi. The ZnO-NPs were tested for antibacterial and antifungal properties shown in (Figure 5 & 6).

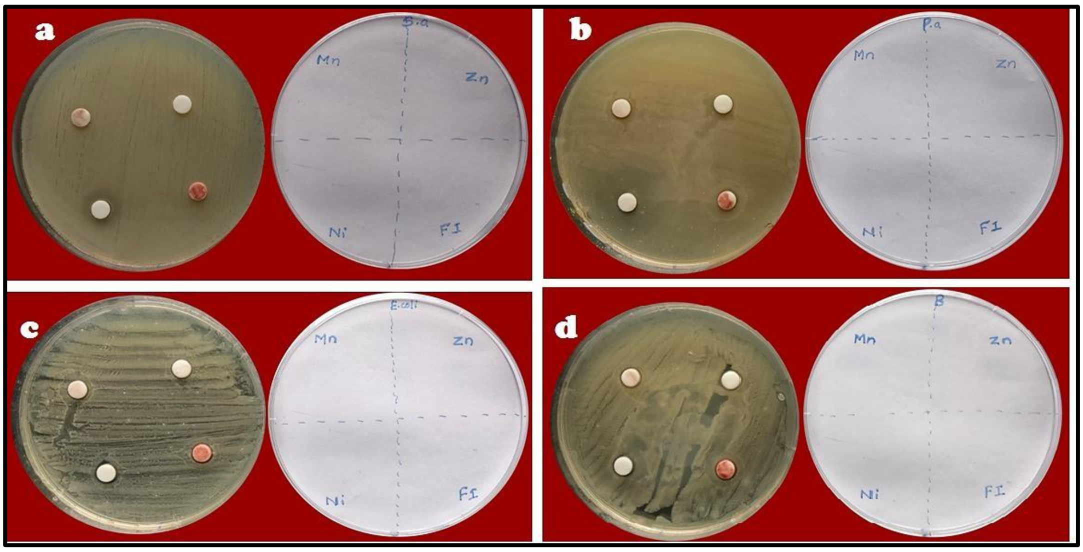

Figure 5 (a) S. aureus (b) B. subtilis (c) E. coli (d) K. pneuminiae

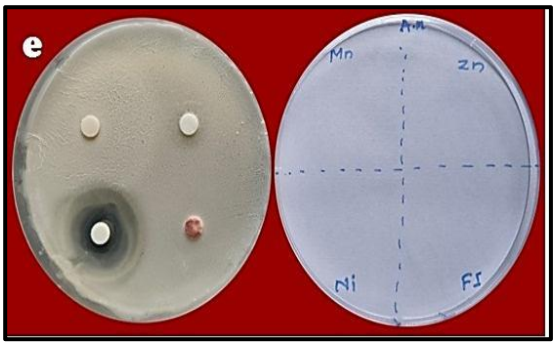

Figure 6(e) A. Niger

The analysis of ZnO-NPs Antibacterial activity and Antifungal activity data showed that, does not exhibits any zone of inhibition. Generally speaking, the effectiveness of a possible antibiotic depends on the particle dose, treatment time, and technique [22].

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