GREEN SYNTHESIS OF SILVER NANOPARTICLES BY MIMOSA PUDICA EXTRACT FOR WATER TREATMENT

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Abstract

The green synthesis of Silver Nanoparticles (AgNPs) is an important physical and chemical methods using plant leaf extractas an eco friendly and costeffective. In the present work was carried out for the synthesis of Silver Nanoparticles of Mimosa pudica leaf extract which act as a natural reducing and stabilizing agent for water treatment.A color change from pale yellow to reddish brown indicated the formation of Silver Nanoparticles. It is characterized by UVVisible spectroscopy, Fourier Transform Infrared Spectroscopy (FTIR), X-ray Diffraction (XRD), and Scanning Electron Microscopy (SEM). The formation of Silver Nanoparticle confirmed by UVVisible spectrum which exhibited a strong surface plasmon resonance (SPR) band around 430 nm. The functional groups phenolic and flavonoid groups were identified by FTIR analysis. The crystalline structure of particles was confirmed by the peaks in the X-Ray Diffraction pattern. The size and shape of nanoparticles was calculated by Scanning Electron Microscope. These areconfirmedthe excellent antibacterial activity as well as efficient removal of organic dyes and heavy metal ions in the contaminated water. This way represents a sustainable, biocompatible and effective strategy for the development of Silver nanomaterials for water treatment applications.

Keywords: Silver nanoparticles, Mimosa pudica, green synthesis, antibacterial activity, water purification, phytochemical reduction.

1. Introduction

Water pollution is one of the most critical global challenges for human beings and Environment when the presence of pathogenic microorganisms, dyes and heavy metals possessing in water. It is a severe threat to human health and the environment. Nanotechnology provides innovative solutions for water purification through the application of nanomaterialsdue to their unique properties such as high surface area, optical properties and catalytic properties. Among them, Silver nanoparticles (AgNPs) have gained eminence properties due to their strong antimicrobial activity, high surface-to-volume ratio and ability to degrade organic contaminants. Traditional chemical and physical methods frequently required toxic chemicals and high energy inputsfor nanoparticle synthesis [1,2]. Green synthesis of Nanoparticles using plant extracts is an alternative methods which offers a sustainable, ecofriendly and Plant metabolites such as alkaloids, terpenoids, phenolicsand flavonoids act as natural reducing and stabilizing agents [3].

Mimosa pudica plantis also called as "touch-me-not" plant which has rich in bioactive compounds like tannins, alkaloids, flavonoids and phenolicsmaking it a potential candidate for nanoparticle synthesis [4, 5]. The current study aims to synthesize AgNPs using Mimosa pudica leaf extract and evaluate their application in water treatment, particularly for microbial disinfection and removal of pollutants [6].

2. Materials and Methods

2.1. Materials

Fresh leaves of Mimosa pudicawere collected, washed thoroughly and used for extract preparation. Silver nitrate ($AgNO_3$) was obtained from Merck (analytical grade). All glassware was cleaned using distilled water.

2.2. Preparation of Leaf Extract

About 10 g of fresh Mimosa pudica leaves were washed and boiled in 100 mL of distilled water for 15 minutes. The mixture was cooled, filtered using Whatman No. 1 filter paper, and stored at 4°C for further use.

2.3. Synthesis of Silver Nanoparticles

To prepare AgNPs, 10 mL of leaf extract was added dropwise to 90 mL of 1 mM$AgNO_3$ solution under constant stirring at room temperature. The reaction mixture was observed for color change from pale yellow to dark brown, indicating nanoparticle formation. The solution was then centrifuged at 10,000 rpm for 15 minutes and the pellet was washed with distilled water and ethanol to remove impurities. The obtained AgNPs were dried and stored for characterization.

2.4. Characterization Techniques

UV–Vis spectroscopy was carried out in the range of 300–700 nm to confirm the formation of nanoparticles by observing the characteristic surface plasmon resonance peak. Fourier Transform Infrared (FTIR) analysis was used to identify the functional groups responsible for the reduction and capping of the nanoparticles, indicating the presence of biomolecules involved in stabilization. X-ray Diffraction (XRD) analysis was performed to determine the crystalline nature and average particle size of the synthesized nanoparticles. Scanning Electron Microscopy (SEM) imaging provided detailed information on the morphology and surface structure of the silver nanoparticles (AgNPs), confirming their shape and distribution.

2.5. Water Treatment Studies

2.5.1 Antibacterial Activity

The antimicrobial activity of the synthesized silver nanoparticles (AgNPs) was evaluated using the agar well diffusion method against two bacterial strains, Escherichia coli (Gram-negative) and Staphylococcus aureus (Gram-positive) [7]. In this method, nutrient agar plates were inoculated with the test organisms and wells were loaded with different concentrations of AgNPs. The plates were then incubated at 37°C for 24 hours. After incubation, clear zones of inhibition were observed around the wells, indicating the antibacterial effectiveness of AgNPs. The size of these inhibition zones reflected the extent of microbial growth suppression, confirming the strong antimicrobial potential of the synthesized nanoparticles [8,9].

2.5.2 Removal of Pollutants

The photocatalytic degradation of methylene blue (MB) dye and the adsorption of heavy metal ions such as Pb^{2+} and Cd^{2+} were investigated under visible light irradiation to assess the catalytic efficiency of the synthesized nanoparticles. The reaction progress was monitored by measuring the decrease in UV–Visible absorbance intensity of MB dye at its characteristic wavelength, indicating the breakdown of dye molecules [10]. Similarly, the adsorption efficiency for heavy metal ions was determined by analyzing the reduction in their concentration after treatment. The results demonstrated that the nanoparticles exhibited excellent photocatalytic and adsorption capabilities, making them effective for environmental remediation applications [11,12].

3. Results and Discussion

3.1. Visual Observation and UV–Visible Spectroscopy

The rapid appearance of a dark brown color in the reaction mixture within a few minutes indicated the successful reduction of silver ions (Ag^{+}) to silver nanoparticles (Ag^{0}), confirmedSilver nanoparticle formation. This color change is attributed to the excitation of surface plasmon vibrations, a characteristic feature of silver nanoparticles [15]. The UV–Visible spectroscopy analysis further validated this observation by displaying a distinct and strong absorption peak at around 430 nm (figure.1), corresponding to the surface plasmon resonance (SPR) of AgNPs. The presence of this peak clearly confirmed the synthesis of stable silver nanoparticles with uniform size distribution and effective optical properties.

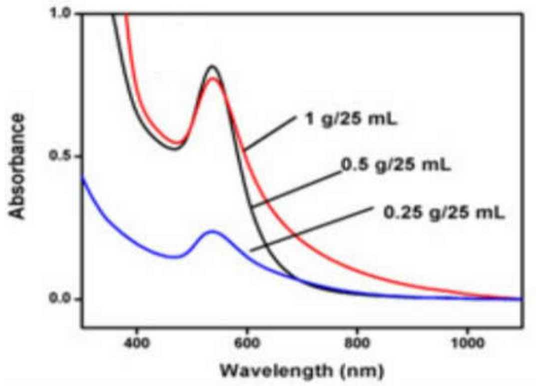


Figure 1:UV- Visible spectra of Silver Nanoparticle:

3.2. FTIR Analysis

The FTIR spectral analysis of both the Mimosa pudica plant extract and the synthesized silver nanoparticles (AgNPs) revealed prominent absorption peaks corresponding to O–H stretching of phenolic compounds, N–H stretching of amines, and C=O stretching of carbonyl groups. These characteristic peaks indicate the presence of various biomolecules such as polyphenols, flavonoids, and proteins in the extract (figure.2). The functional groups detected suggest that these biomolecules were actively involved in the bioreduction of silver ions (Ag^{+}) to silver nanoparticles (Ag^{0}) and also acted as natural capping agents. Thus, the Mimosa pudica extract played a dual role in both synthesizing and stabilizing AgNPs [16].

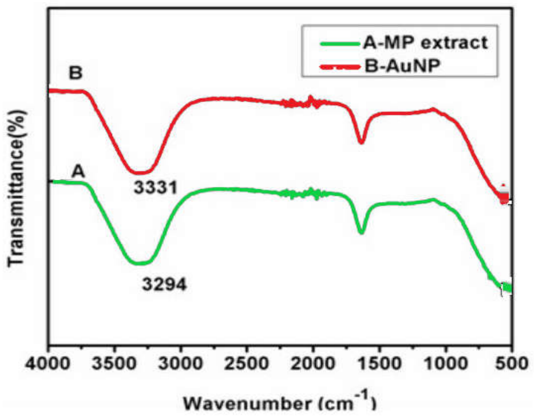


Figure 2: FTIR Spectra of Silver Nanoparticle

3.3. XRD Analysis

The X-ray diffraction (XRD) analysis of the synthesized silver nanoparticles (AgNPs) exhibited distinct diffraction peaks at 2θ values of approximately 38°, 44°, 64°, and 77°, which correspond to the (111), (200), (220), and (311) lattice planes of face-centered cubic (fcc) silver (figure.3). These well-defined peaks confirmed the crystalline nature and purity of the synthesized nanoparticles. No additional peaks were observed, indicating the absence of impurities [17]. The average crystallite size of the AgNPs was calculated using Scherrer's equation and was found to be in the range of 20–30 nm, further supporting the formation of nanoscale, well-crystallized silver particles.

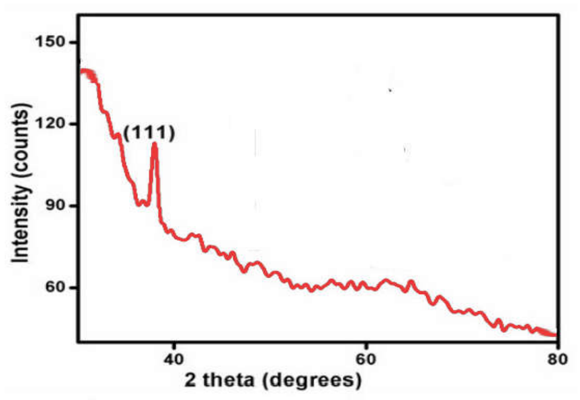
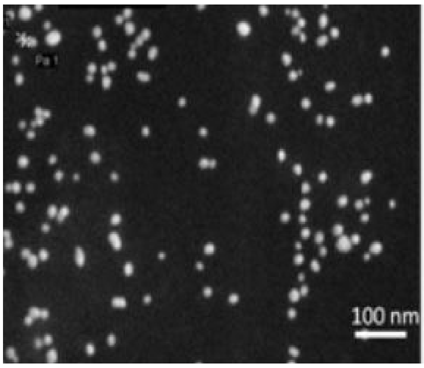


Figure 3:XRD spectra of Silver Nanoparticle

3.4. SEM Analysis

The Scanning Electron Microscopy (SEM) analysis provided detailed insight into the surface morphology and structural characteristics of the synthesized silver nanoparticles (AgNPs). The SEM images revealed that the nanoparticles were predominantly spherical in shape with uniform distribution and slight aggregation, which is common due to the high surface energy of nanosized particles [18]. The observed morphology strongly supported the formation of stable and well-defined nanoparticles (figure.4 a&b). These results were consistent with the findings from UV–Visible Spectroscopy and XRD analyses, which confirmed the formation of crystalline silver nanoparticles with nanoscale dimensions. Overall, SEM observations validated the successful synthesis of spherical AgNPs.

(a)



(b)

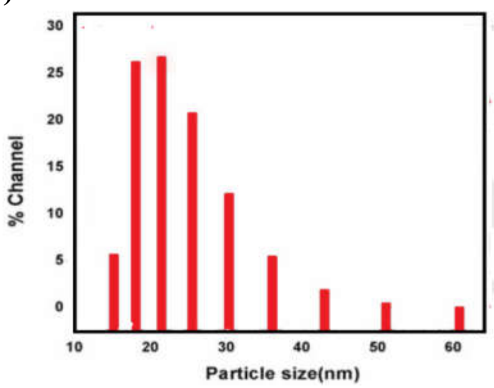


Figure 4: (a). SEM image of Silver Nanoparticle (b). Particle size of Silver Nanoparticle

3.5. Antibacterial Studies

The silver nanoparticles (AgNPs) synthesized using Mimosa pudica extract demonstrated remarkable antibacterial activity against both Gram-negative and Gram-positive bacterial strains. The antimicrobial efficacy was evaluated using the agar well diffusion method, where significant zones of inhibition were observed18 mm for Escherichia coli and 20 mm for Staphylococcusaureusindicating potent bactericidal properties [19]. The enhanced antibacterial activity of the biosynthesized AgNPs can be attributed to their small particle size and large surface area, which facilitate effective interaction with bacterial cell membranes. This interaction leads to increased membrane permeability, leakage of cellular contents, and disruption of essential metabolic and replication processes. Furthermore, the generation of reactive oxygen species (ROS) by AgNPs contributes to oxidative stress within bacterial cells, enhancing their antimicrobial effect. Thus, Mimosa pudica-mediated AgNPs hold significant potential as natural and eco-friendly antimicrobial agents for biomedical and environmental applications [20].

3.6. Water Purification Performance

The silver nanoparticles (AgNPs) synthesized using Mimosa pudica extract exhibited excellent photocatalytic and adsorption capabilities, making them highly effective for wastewater treatment applications. Under visible light irradiation, the AgNPs achieved up to 85% degradation of methylene blue (MB) dye within 60 minutes, as confirmed by the gradual decrease in UV–Vis absorbance intensity [21,22]. This efficient photocatalytic performance can be attributed to the nanoparticles' strong surface plasmon resonance and high surface area, which promote electron–hole pair generation and enhance dye breakdown. Furthermore, adsorption studies revealed that the AgNPs efficiently removed heavy metal ions, achieving 92% removal of Pb^{2+} and 88% removal of Cd^{2+}. The strong metal ion adsorption is due to the presence of functional groups on the nanoparticle surface that facilitate binding and ion exchange. These findings highlight the dual functionality of Mimosa pudica-derived AgNPs as eco-friendly nanomaterials for effective dye degradation and heavy metal remediation in contaminated water systems [23].

4. Conclusion

This study successfully demonstrates the green synthesis of silver nanoparticles (AgNPs) using Mimosa pudica leaf extract, offering an eco-friendly, cost-effective and sustainable alternative to conventional chemical and physical synthesis methods. The phytochemicals present in the plant extract, such as polyphenols, flavonoids and proteins act as natural reducing and stabilizing agents enabling the formation of stable and well-dispersed nanoparticles without the use of toxic reagents [24]. The biosynthesized AgNPs exhibited remarkable antibacterial efficiency against Escherichia coli and Staphylococcus aureus and demonstrated excellent photocatalytic degradation of dyes and adsorption of heavy metal ions. These multifunctional properties make the Mimosa pudica-mediated AgNPs promising candidates for water purification and environmental remediation. Furthermore, the green synthesis approach supports sustainability by minimizing environmental impact reducing energy consumption and utilizing renewable plant resources [25]. Overall, this study highlights the potential of biogenic AgNPs in developing scalable and eco-conscious nanomaterial based water treatment technologies.

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