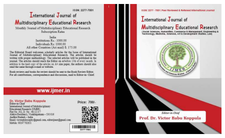
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GREEN BIOGENIC NOBLE METAL NANOPARTICLES: A REVIEW

Md. Niharul Alam
Assistant Professor, Department of Chemistry,
Jalpaiguri Government Engineering College, Jalpaiguri, West Bengal, India

Abstract

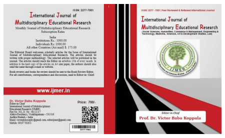
Nanoparticles, especially noble metals, have attracted considerable interest recently due to their distinctive properties and wide-ranging applications in medicine, electronics, and environmental remediation. Conventional methods for synthesizing metal nanoparticles often involve hazardous chemicals and high-energy processes, raising the need for more sustainable alternatives. This has led to the development of green biogenic synthesis, which utilizes plant extracts or microorganisms as an eco-friendly approach. This review explores the significance of noble metal nanoparticles, the principles of green chemistry in their synthesis, and various biogenic synthesis methods with a focus on plant-based protocols. We examine this method's advantages, challenges, and prospects for producing nanoparticles with precisely tailored properties.

1. Noble metal nanoparticles and their importance

Noble metal nanoparticles (NMNPs), such as gold (Au), silver (Ag), platinum (Pt), and palladium (Pd), have garnered significant attention in nanoscience and nanotechnology due to their unique properties that are fundamentally different from their bulk counterparts.[1,2,3] These properties include distinct electronic, optical, catalytic, and antimicrobial behaviors, highly dependent on their size and surface area. The high surface-to-volume ratio of these nanoparticles enhances their reactivity. It makes them ideal for various applications, from catalysis to biosensing, drug delivery, and antimicrobial treatments.[4-7] The size-dependent properties of noble metal nanoparticles enable enhanced performance and tunability, making them versatile in scientific research and industrial applications.

Here is a tabular and graphical format summarizing the key points on noble metal nanoparticles and their importance:

Property/Application	Description
Electronic & Optical Properties	NMNPs exhibit unique electronic behaviors, such as surface plasmon resonance (SPR), which enhances light absorption and scattering at specific wavelengths. SPR is particularly pronounced in gold nanoparticles (AuNPs) and silver nanoparticles (AgNPs), making them ideal for biosensors and imaging applications.[1,3,8]
Catalytic Properties	NMNPs, such as platinum nanoparticles (PtNPs),[9] $ palladium nanoparticles (PdNPs),[10] and AuNPs[1,3,11] are highly sought after for their catalytic efficiency. They are useful in reactions such as hydrogenation, oxidation, and fuel cell technology. Their high surface-to-volume ratio enables better interaction with reactants.
Biomedical Applications	AuNPs and AgNPs are widely used in drug delivery and imaging.[12] Their biocompatibility allows controlled drug release at specific sites, reducing side effects. AuNPs also serve as contrast agents in CT and MRI scans, enhancing the visibility of biological tissues.
Antimicrobial Properties	AgNPs are known for their antimicrobial activity, which disrupts microbial cell membranes and DNA. AgNPs are incorporated into wound dressings and medical devices to prevent infections. The size and shape of AgNPs influence their antimicrobial efficacy.[13]
Environmental Applications	NMNPs, especially AuNPs and AgNPs, effectively remove pollutants like heavy metals, dyes, and organic contaminants from water sources. They are employed in water treatment and environmental remediation via adsorption, photocatalysis, and degradation processes.[14]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2. Metal nanoparticle synthesis methods and their drawbacks

The synthesis of metal nanoparticles (MNPs) can be broadly categorized into **physical** and **chemical** methods,[15]each with its own set of advantages and drawbacks. Although these methods have been widely used to create high-quality nanoparticles, they are often criticized for their environmental impact, high costs, and energy requirements. In recent years, this has driven researchers to explore more sustainable alternatives, such as **green synthesis**, which is discussed further below.

2.1. Physical methods of metal nanoparticle synthesis

Physical methods for synthesizing MNPs have attracted significant interest due to their ability to produce high-purity, highly crystalline nanoparticles without needing chemical reagents.[16] These methods typically rely on physical energy (heat, light, or mechanical forces) to induce the formation of nanoparticles from bulk metal precursors or metal-containing materials. A detailed outline of standard physical methods used for the synthesis of MNPs, including electric arc discharge, flame pyrolysis, ball milling, laser ablation is tabulated below.

Method	Description	Advantages	Drawbacks	Ref.
Electric Arc Discharge	An electric arc is created between two metal electrodes in an argon atmosphere, vaporizing the metal and condensing it into nanoparticles.	High purity: No chemical reagents used. Versatility: Can be applied to various noble metals (gold, silver, platinum).	High energy consumption: Requires substantial electrical energy. Limited control over size and morphology.	17
Flame Pyrolysis	Metal precursors are introduced into a flame, where they decompose to form nanoparticles, typically at high temperatures in an oxidizing/inert gas environment.	High production rate: Capable of synthesizing large quantities quickly. Control over composition: Can adjust precursor and flame conditions to control nanoparticle size.	Agglomeration: High temperatures can cause particle agglomeration. Size distribution: Narrow size distribution is challenging to achieve.	18
Ball Milling	Bulk metal is ground in a rotating cylinder with grinding media (balls) to create fine powders and nanoparticles.	Low cost: A relatively inexpensive method suitable for large-scale production. No chemical reagents are required, which reduces environmental impact.	Contamination risk: Grinding media can introduce impurities. Wide size distribution: Achieving uniform nanoparticle sizes is challenging.	19
Laser Ablation	A high-intensity laser beam irradiates a metal target in a liquid medium, vaporizing the metal and forming nanoparticles in the surrounding liquid.	High purity: No chemicals are used, leading to pure nanoparticles. Size and shape control: The size and shape of nanoparticles can be controlled by adjusting laser parameters.	High energy consumption: Energy-intensive process, limiting scalability. Limited throughput: Not ideal for large-scale production due to high operational costs.	20

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2.2. Chemical methods of metal nanoparticle synthesis

Chemical methods are commonly used to synthesize metal nanoparticles, leveraging chemical reactions to reduce metal ions to their metallic nanoparticle form. These methods provide precise control over the size, shape, and uniformity of nanoparticles but often come with environmental and health safety alarms due to the use of toxic reagents and solvents.[21] Below are three prominent chemical approaches for metal nanoparticle synthesis.

Method	Description	Advantages	Drawbacks	Ref.
Chemical Reduction	Involves reducing metal salts (e.g., gold chloride) using a chemical reducing agent like hydrazine or sodium borohydride.	High uniformity: Produces nanoparticles with controlled size and shape. Easy to scale up.	Toxic chemicals: Hazardous reducing agents (hydrazine, sodium borohydride) pose environmental and health risks. Waste disposal: Requires careful disposal of chemical waste.	22
Solvothermal Synthesis	It uses high temperatures and pressures in a solvent to facilitate nanoparticle formation and is often employed for more complex nanoparticles.	Precise control: Allows fine control over size and morphology. Suitable for complex nanoparticles.	Toxic solvents: Often require hazardous and toxic solvents. High energy consumption: Energy-intensive process.	23
Polyol Method	Involves using a polyol (e.g., ethylene glycol) as the solvent and reducing agent to form nanoparticles.	Size and shape control: Provides reasonable control over the size and shape of nanoparticles. Simplicity: Simple procedure.	High temperatures: Requires elevated temperatures for synthesis. Organic solvents: The use of organic solvents presents environmental concerns.	24

3. Green synthesis of metal nanoparticles

The drawbacks of conventional physical and chemical methods have invigorated the development of alternative approaches for nanoparticle synthesis, particularly those based on **green chemistry** principles.[25] Green synthesis, also referred to as **biogenic synthesis**, employs environmentally friendly reagents and processes that minimize waste and toxicity.[26] The use of plant extracts, bacteria, fungi, or algae to reduce metal ions to their nanoparticle form has garnered significant attention. In **green synthesis**, bioactive compounds in plant extracts (such as flavonoids, alkaloids, and terpenoids) act as reducing and stabilizing agents, ensuring that MNPs are synthesized and controlled and achieve the desired size, shape, and uniformity. Unlike traditional chemical methods, which often rely on harsh chemicals and high temperatures, green synthesis can run under mild conditions, such as ambient temperature and pressure.[3,4,5,7,27,28] & This makes the process not only environmentally friendly but also energy-efficient.

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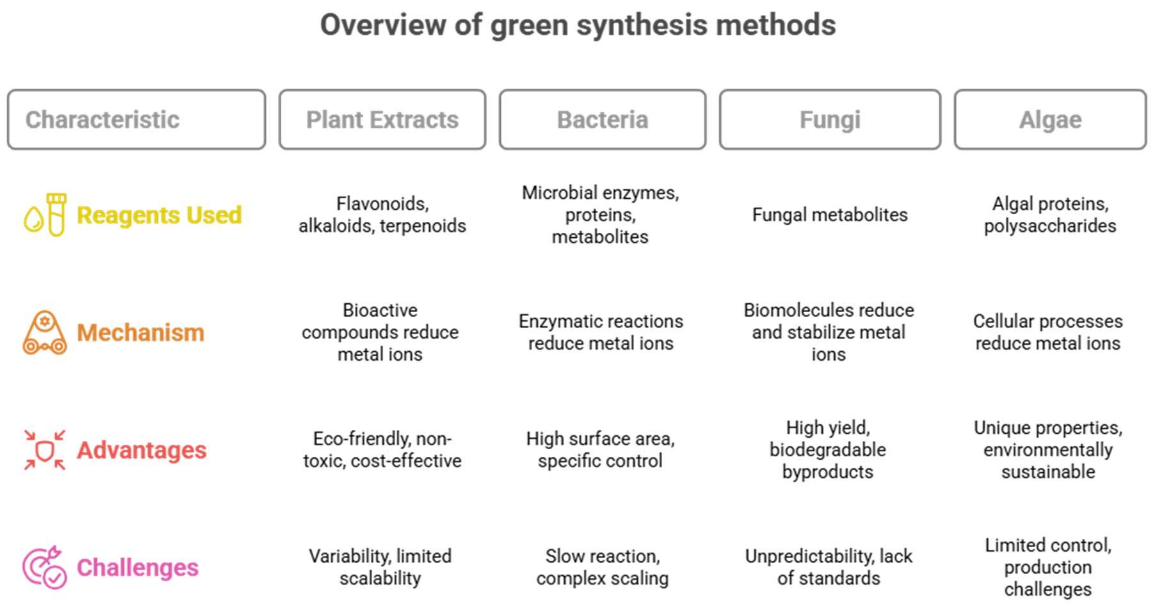


Overview of green synthesis methods

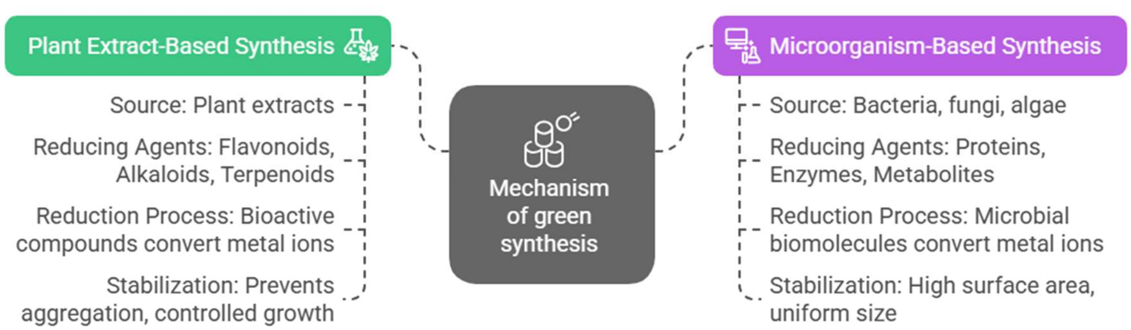
Characteristic	Plant Extracts	Bacteria	Fungi	Algae
Reagents Used	Flavonoids, alkaloids, terpenoids	Microbial enzymes, proteins, metabolites	Fungal metabolites	Algal proteins, polysaccharides
Mechanism	Bioactive compounds reduce metal ions	Enzymatic reactions reduce metal ions	Biomolecules reduce and stabilize metal ions	Cellular processes reduce metal ions
Advantages	Eco-friendly, non-toxic, cost-effective	High surface area, specific control	High yield, biodegradable byproducts	Unique properties, environmentally sustainable
Challenges	Variability, limited scalability	Slow reaction, complex scaling	Unpredictability, lack of standards	Limited control, production challenges

Mechanisms of green synthesis

- **Plant Extracts**: Plant-based methods have gained attention because they are rich in bioactive compounds such as flavonoids, alkaloids, and terpenoids. These compounds act as reducing agents, enabling the reduction of metal ions into their nanoparticle form. Additionally, these compounds help to stabilize the nanoparticles by preventing aggregation and ensuring controlled growth.

- **Microorganisms**: Various microorganisms, including bacteria, fungi, and algae, have shown potential in reducing metal ions to nanoparticles. These microorganisms produce biomolecules that can reduce metal ions and stabilize the formed nanoparticles, often resulting in unique properties such as high surface area and uniform size.

4. Are plant-based biogenic synthetic protocols more advantageous?



Plant-based biogenic synthesis protocols have gained significant attention due to their numerous advantages. Unlike microbial systems, plants are easy to cultivate, require minimal space, and can be scaled up easily. Additionally, plants offer a diverse range of bioactive compounds, such as polyphenols, alkaloids, and flavonoids. These bioactive compounds can reduce metal ions and stabilize nanoparticles. They not only reduce the metal ions but also provide capping agents that can prevent aggregation and control particle growth.[3,4,5,7,27,28]

Furthermore, the use of plant extracts reduces the need for additional reagents, making the process more cost-effective. Recent studies have demonstrated that plant-based protocols can produce nanoparticles with controlled sizes, shapes, and surface properties, which are crucial for applications in targeted drug delivery and biosensing.[29,30]
Here is the table summarizing the advantages of plant-based biogenic synthesis:

Advantage	Description
Scalability and Ease of Cultivation	Plant-based synthesis is easier to scale up compared to microbial systems. Plants are easier to cultivate, can grow in various environments, require less space, and can be harvested year-round, making them ideal for large-scale production.
Diversity of Bioactive Compounds	Plants produce compounds like polyphenols, flavonoids, alkaloids, and terpenoids, which reduce metal ions and act as stabilizing agents for nanoparticles. This reduces the need for additional reagents, making the process more sustainable.
Cost-Effectiveness	Plant extracts are low-cost, renewable, and abundant. This significantly reduces the need for expensive reagents and solvents, lowering the environmental impact and disposal costs, making plant-based synthesis more economically viable.
Control Over Size, Shape, and Surface Properties	Plant extracts offer control over the size, shape, and surface properties of nanoparticles, which is crucial for applications like drug delivery, imaging, and biosensing. These properties can be adjusted by manipulating the synthesis conditions.
Environmental and Health Benefits	The process is eco-friendly, using natural, biodegradable plant extracts instead of toxic chemicals. It also operates under mild conditions, reducing energy consumption and contributing to a lower carbon footprint.
Antimicrobial and Biomedical Applications	Plant-derived nanoparticles, such as those from cinnamon, neem, and turmeric, show enhanced antimicrobial properties. They are also biocompatible and low in toxicity, making them ideal for biomedical applications like drug delivery and wound healing.
Sustainability and Green Chemistry	Plant-based synthesis aligns with green chemistry principles, avoiding toxic chemicals and reducing pollution. It supports sustainability goals and promotes a circular economy, with many plant species being locally sourced.

This table consolidates the key advantages of plant-based biogenic synthesis, providing a concise overview of the benefits and demonstrating its potential across various industries.

5. Achievements in the field of biogenic synthesis of noble metal nanoparticles

Recent advancements in the biogenic synthesis of noble metal nanoparticles (NMNPs) have attracted significant attention in the fields of nanotechnology, medicine, and environmental science.[3,4,5,7,27,28] Biogenic methods, particularly those utilizing plant-based systems, offer a sustainable, cost-effective, and eco-friendly approach to nanoparticle synthesis. The use of plant extracts for the synthesis of noble metal nanoparticles (such as gold, silver, copper, and palladium) has shown substantial promise, particularly due to their ease of use, ability to fine-tune nanoparticle properties, and their non-toxic nature.

Key achievement of biogenic synthesis of noble metal nanoparticles

i) **Enhanced Properties**: Plant-based synthesis allows for the production of nanoparticles with fine-tuned properties such as high surface area, stability, and uniform size distribution.

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ii) **Eco-Friendly**: The use of plant extracts in nanoparticle synthesis reduces the environmental impact by avoiding toxic chemicals and minimizing energy consumption.
iii) **Scalability**: Biogenic synthesis methods can be easily scaled up, making them viable for industrial-scale production of nanoparticles.
iv) **Functionalization**: Plant-derived nanoparticles can be easily functionalized for specific applications, such as drug delivery, environmental remediation, and biosensing.

I. Gold Nanoparticles (AuNPs)

Gold nanoparticles have gained widespread recognition for their biomedical applications, including drug delivery, imaging, and diagnostics and some short of catalytic activty. Recent studies have demonstrated that plant extracts are excellent reducing and stabilizing agents for the synthesis of gold nanoparticles with specific properties.[3,7,31]

II. Silver Nanoparticles (AgNPs)

Silver nanoparticles have been extensively studied due to their remarkable antibacterial, antiviral, and anticancer properties. Recent plant-based approaches to silver nanoparticle synthesis have resulted in nanoparticles with enhanced biocompatibility and tunable physicochemical properties.[4,32]

III. Palladium Nanoparticles (PdNPs)

Palladium nanoparticles are widely used in catalytic processes and environmental applications due to their high catalytic activity and stability. Biogenic synthesis methods have enabled the production of palladium nanoparticles with high activity and selectivity.[33,34]

IV. Platinum Nanoparticles (PtNPs)
Platinum nanoparticles are renowned for their outstanding catalytic, anticancer, and antioxidant properties. Their unique physicochemical characteristics make them highly suitable for applications in medicine, environmental remediation, and catalysis. Recent studies have demonstrated that plant-mediated synthesis of platinum nanoparticles offers a green, cost-effective, and eco-friendly alternative to conventional methods.[9,35]

6. Plant-based biogenic synthetic protocols

The general procedure for plant-based biogenic synthesis typically involves preparing an aqueous extract from the plant material, followed by the addition of a metal salt solution. The metal ions are reduced by bioactive components in the plant extract, leading to the formation of metal nanoparticles. The size and morphology of the nanoparticles can be influenced by factors such as the concentration of the metal salt, temperature, pH, and the type of plant extract used.[7] Plant-based protocols have been successfully employed for the synthesis of a wide range of metal nanoparticles, including gold, silver, palladium, and platinum.

General procedure for plant-based biogenic synthesis of metal nanoparticles

i) **Preparation of Plant Extract:**
   - The first step involves preparing an aqueous extract from plant materials, which can include leaves, stems, flowers, or roots. The plant material is thoroughly washed to remove surface contaminants, ground, and then boiled in distilled water to extract bioactive compounds such as polyphenols, flavonoids, and terpenoids. After boiling, the solution is filtered to obtain a clear plant extract free of solid residues.

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ii) **Addition of Metal Salt Solution:**
   - A solution containing metal salts (e.g., gold chloride, silver nitrate, palladium chloride, or platinum chloride) is prepared. This metal salt solution is then carefully mixed with the plant extract. The metal ions in the solution interact with the bioactive compounds in the extract, initiating the reduction of metal ions into their elemental nanoparticle form.

iii) **Reduction of Metal Ions:**
   - Bioactive compounds like polyphenols and flavonoids serve as reducing agents that convert metal ions into metal nanoparticles. This reduction process typically occurs at room temperature or under mild heating conditions. The choice of plant extract and metal salt influences the speed and efficiency of the reduction process.

iv) **Formation of Metal Nanoparticles:**
   - As the metal ions are reduced, they begin to form nanoparticles. The size and shape of the nanoparticles can vary depending on the concentration of the metal ions, temperature, and the type of plant extract. The plant extract also stabilizes the nanoparticles, preventing them from aggregating and ensuring uniform growth.

v) **Characterization of Nanoparticles:**
   - Once the nanoparticles are formed, they are characterized using various techniques, including UV-Vis spectroscopy, transmission electron microscopy (TEM), scanning electron microscopy (SEM), X-ray diffraction (XRD), and Fourier transform infrared spectroscopy (FT-IR). These methods help in determining the size, shape, and surface properties of the nanoparticles.

7. Interaction of bioactive components and mechanistic pathways

The synthesis of metal nanoparticles through plant-based biogenic methods is a complex process that relies heavily on the interaction between bioactive components in plant materials and metal ions. Bioactive compounds such as polyphenols, flavonoids, terpenoids, and proteins are integral to the reduction and stabilization of metal ions. These compounds not only serve as reducing agents but also play a crucial role in capping the nanoparticles, preventing agglomeration and ensuring their stability in solution. The reduction process typically involves the donation of electrons from these compounds to the metal ions, which reduces them to their elemental forms, resulting in nanoparticle formation.[3,4,7]

In addition to their reducing and stabilizing roles, these bioactive components also influence the size, shape, and surface properties of the nanoparticles. For instance, polyphenols and flavonoids are known for their strong reducing ability and are often responsible for the formation of smaller, more uniform nanoparticles. On the other hand, terpenoids and proteins may contribute to the stabilization and functionalization of the nanoparticles, making them suitable for various applications such as drug delivery, environmental remediation, and biosensing.

Mechanistic pathways of nanoparticle formation

Understanding the mechanistic pathways of nanoparticle formation is essential for optimizing the synthesis process and obtaining nanoparticles with the desired properties. The mechanism generally involves the following steps:

i) **Reduction of metal ions:** Bioactive compounds in the plant extract donate electrons to the metal ions, reducing them to their elemental state.
ii) **Nucleation:** As the metal ions are reduced, they begin to cluster and form small clusters or nuclei.
iii) **Growth:** These nuclei grow into nanoparticles as more metal ions are reduced and added to the existing clusters.
iv) **Stabilization:** The bioactive compounds in the plant extract act as capping agents, preventing the nanoparticles from agglomerating and ensuring their uniformity and stability.

8. Challenges and future scope of plant-based biogenic synthesis

While plant-based biogenic synthesis of nanoparticles offers many advantages, including sustainability and environmental friendliness, several challenges persist that need to be addressed for wider applicability and commercial success. The

primary hurdles include the variability in plant extract composition, difficulty in controlling nanoparticle size and shape, and the challenges of scaling the synthesis process from laboratory to industrial scale.
Despite the challenges, there are several promising solutions and directions for improving the plant-based biogenic synthesis process.

Challenges and potential solutions in plant-based biogenic synthesis		
Challenge	**Description**	**Potential Solution**
Variability in Plant Extracts	Differences in bioactive compounds among plant species and environmental factors lead to inconsistent synthesis.	Use of standardized plant extracts and selection of consistent species for higher reproducibility.
Control Over Size, Shape, and Distribution	Achieving uniform size, shape, and distribution of nanoparticles is difficult with plant-based methods.	Further research into the mechanistic pathways of nanoparticle formation and optimization of reaction parameters.
Scaling Up the Process	Maintaining control over nanoparticle quality when scaling from laboratory to industrial scale is challenging.	Use of bioreactors for controlled synthesis on a larger scale, automation for better efficiency, and cost management strategies.
Sustainability and Environmental Concerns	Ensuring the process remains environmentally friendly and cost-effective at large scales.	Integrating green chemistry principles, optimizing energy consumption, and reducing toxic chemicals.

Conclusion

The green biogenic synthesis of noble metal nanoparticles presents a promising and sustainable alternative to conventional methods. Plant-based protocols stand out due to their scalability, ease of use, and ability to produce nanoparticles with fine-tuned properties. However, challenges remain in terms of reproducibility, scalability, and precise control over nanoparticle characteristics. Through continued research and optimization, biogenic synthesis has the potential to revolutionize the production of noble metal nanoparticles across various industries, paving the way for more sustainable and environmentally friendly applications.

References

1. AK Khan, R Rashid, G Murtaza, A Zahra (2014) Gold Nanoparticles: Synthesis and Applications in Drug Delivery. Trop J Pharm Res 13: 1169-1177.
2. KS Lee , MA El-Sayed (2006) Gold and silver nanoparticles in sensing and imaging: sensitivity of plasmon response to size, shape, and metal composition. J Phys Chem B 110(39): 19220–19225.
3. MN Alam , S Batuta, G Ahamed, S Das , D Mandal , NA Begum (2019) Tailoring the catalytic activity of Au nanoparticles synthesized by a naturally occurring green multifunctional agent. Arabian J Chem 12: 3825-3835.
4. MN Alam , A Chatterjee, S Das, S Batuta, D Mandal , NA Begum (2015) Burmese grape fruit juice can trigger the “logic gate” like colorimetric sensing behavior of Ag nanoparticles towards toxic metal ion. RSC Adv 5: 23419–23430.
5. MN Alam , N Roy , D Mandal, NA Begum (2013) Green chemistry for nanochemistry: exploring medicinal plants for the biogenic synthesis of metal NPs with fine-tune properties, RSC Adv 3: 11935-11956.
6. PB Santhosh , J Genova, H Chamati (2022) Green Synthesis of Gold Nanoparticles: An Eco-Friendly Approach. Chemistry *4*(2): 345-369.

7. MN Alam , S Das, S Batuta, N Roy, A Chatterjee, D Mandal , NA Begum (2014) Murraya koenegii Spreng. Leaf Extract: An Efficient Green Multifunctional Agent for the Controlled Synthesis of Au Nanoparticles. ACS Sust Chem & Eng 2: 652−664.
8. G Alberti, C Zanoni, LR Magnaghi, R Biesuz (2021) Gold and Silver Nanoparticle-Based Colorimetric Sensors: New Trends and Applications. Chemosensors 9(11): 305.
9.AS Eltaweil, M Fawzy, M Hosny, EMA El-Monaem, TM Tamer, AM Omer (2022) Green synthesis of platinum nanoparticles using *Atriplex halimus* leaves for potential antimicrobial, antioxidant, and catalytic applications. Arabian Journal of Chem 15(1): 103517.
10.S Lebaschi, M Hekmati, H Veisi (2017) Green synthesis of palladium nanoparticles mediated by black tea leaves (*Camellia sinensis*) extract: Catalytic activity in the reduction of 4-nitrophenol and Suzuki-Miyaura coupling reaction under ligand-free conditions. Journal of Colloid and Interf Sc 485(1) 223-231.
11.OM El-Borady, MS Ayat, MA Shabrawy, P Millet (2020) Green synthesis of gold nanoparticles using Parsley leaves extract and their applications as an alternative catalytic, antioxidant, anticancer, and antibacterial agents. Advanced Powder Technology 31: 4390-4400.
12.SM Nadaf, NR Jadhav, HS Naikwadi, PL Savekar, ID Sapkal, MM Kambli, IA Desai (2022) Green synthesis of gold and silver nanoparticles: Updates on research, patents, and future prospects. Open Nano 8: 100076.
13. S Veena, T Devasena, SSM Sathak, M Yasasve, LA Vishal (2019) Green Synthesis of Gold Nanoparticles from Vitex negundo Leaf Extract: Characterization and In Vitro Evaluation of Antioxidant–Antibacterial Activity. Journal of Cluster Sc 30: 1591–1597.
14. WM Alamier, MDY Oteef, AM Bakry, N Hasan, KS Ismail, FS Awad (2023) Green Synthesis of Silver Nanoparticles Using Acacia ehrenbergiana Plant Cortex Extract for Efficient Removal of Rhodamine B Cationic Dye from Wastewater and the Evaluation of Antimicrobial Activity. ACS Omega 8(21): 18901-18914.
15.S Kumari, S Raturi, S Kulshrestha, K Chauhan, S Dhingra, K András, KT hu, R Khargotra, T Singh (2023) A comprehensive review on various techniques used for synthesizing nanoparticles. Journal of Materials Research and Technology 27: 1739-1763.
16. N Al-Harbi, NK Abd-Elrahman (2025) Physical methods for preparation of nanomaterials, their characterization and applications: a review. *J.Umm Al-Qura Univ. Appll. Sci.* 11: 356–377.
17. S Musikhin, V Nemchinsky, Y Raitses (2024) Growth of metal nanoparticles in hydrocarbon atmosphere of arc discharge. Nanotechnology 35: 385601.
18. Z Chen, Z Xu, H Zhao (2021) Flame spray pyrolysis synthesis and H_2S sensing properties of CuO-doped SnO_2 nanoparticles. Proceedings of the Combustion Institute 38: 6743-6751.
19. J Joy, A Krishnamoorthy, A Tanna, V Kamathe, R Nagar, S Srinivasan (2022) Recent Developments on the Synthesis of Nanocomposite Materials via Ball Milling Approach for Energy Storage Applications. Applied Sci 12: 9312.
20.A Balachandran, SP Sreenilayam, K Madanan, S Thomas, D Brabazon (2022) Nanoparticle production via laser ablation synthesis in solution method and printed electronic application - A brief review. Results in Engineering 16: 100646.
21. M Fahim, A Shahzaib, N Nishat , A Jahan, TA Bhat , A Inam (2024) Green synthesis of silver nanoparticles: A comprehensive review of methods, influencing factors, and applications. JCIS Open 100125.
22. P Szczyglewska, A Feliczak-Guzik, I Nowak (2023) Nanotechnology–General Aspects: A Chemical Reduction Approach to the Synthesis of Nanoparticles. Molecules 28: 4932.
23.J Li, Q Wu, J Wu (2015). Synthesis of Nanoparticles via Solvothermal and Hydrothermal Methods. In: Aliofkhazraei, M. (eds) Handbook of Nanoparticles. Springer, Cham.
24. F. Fiévet, S Merah, R Brayner, F Chau, M Giraud, J Peron, JY Piquemal, L Sicard, G Viau (2018) The polyol process: a unique method for easy access to metal nanoparticles with tailored sizes, shapes and compositions. Chemical Society Reviews 47(14).
25. PT Anastas, JC Warner. (1998) *Green Chemistry: Theory and Practice*. Oxford University Press.
26. A Moores (2023) Green Synthesis of Nanoparticles: Pioneering Sustainable Technology. J Nanosci Nanotechnol 7:12.
27. KT Khac, HH Phu, HT Thi, V Dinh, Hue Do Thi (2023) Biosynthesis of silver nanoparticles using tea leaf extract (camellia sinensis) for photocatalyst and antibacterial effect. Heliyon 9 e20707

Cover Page

INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY EDUCATIONAL RESEARCH
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28. NS Alharbi, NS Alsubhi (2023) Silver Nanoparticles Biosynthesized Using Azadirachta indica Fruit and Leaf Extracts: Optimization, Characterization, and Anticancer Activity. Journal of Nanomaterials, Article ID 9916777, 1-17.
29. X Xiao, C Wang, Z Guo, D Guo, W Lai, J Peng (2019) Gold Nanoparticle-Based Paper Sensor for Highly Specific Detection of Ofloxacin in Beef. J Food Chem Nanotechnol 5(4): 72-78.
30. A Rónavári, NIgaz, DI Adamecz, B Szerencsés, C Molnar, Z Kónya, I Pfeiffer, M Kiricsi (2021) Green Silver and Gold Nanoparticles: Biological Synthesis Approaches and Potentials for Biomedical Applications. Molecules 26: 844.
31. S Balasubramanian, SMJ Kala, TL Pushparaj (2020) Biogenic synthesis of gold nanoparticles using Jasminum auriculatum leaf extract and their catalytic, antimicrobial and anticancer activities. Journal of Drug Delivery Science and Technology 57: 101620.
32. UP Manik, A Nande, S Raut, SJ Dhoble (2020) Green synthesis of silver nanoparticles using plant leaf extraction of Artocarpus heterophylus and Azadirachta indica. Results in Materials 6:100086.
33. L Natrayan, Y Devarajan (2023) Catalytic activities of oxidation on hydrazine and azo-dye of nano palladium particles synthesis from bio-waste Cinnamomum camphora leaf extract. Biomass Conv Bioref 13: 15135–15148.
34. C Garai, SN Hasan, AC Barai, S Ghorai, SKPanja, BG Bag (2018) Green synthesis of Terminalia arjuna-conjugated palladium nanoparticles (TA-PdNPs) and its catalytic applications. J Nanostruct Chem 8: 465–472.
35. A Azad, S Hussain, H Akram, H Fida, MA Iqbal, TE Butt (2024) Environmentally-friendly synthesis of platinum nanoparticles: phytochemical, antioxidant, and antimicrobial properties of Cichorium intybus in different solvents. Discov Plants 1: 24.