Green Synthesis of Metalic Nanoparticles

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Abstract—**Green synthesis is an eco-friendly method for creating metallic nanoparticles (MNPs) by using biological sources like plants, algae, or microorganisms to reduce metal ion precursors. The biological materials contain compounds such as polyphenols, proteins, and sugars that act as both reducing and stabilizing agents, converting metal ions into stable MNPs. The process involves mixing a biological extract with a metal salt solution, which triggers a color change indicating MNP formation, followed by growth and stabilization into a final product.**

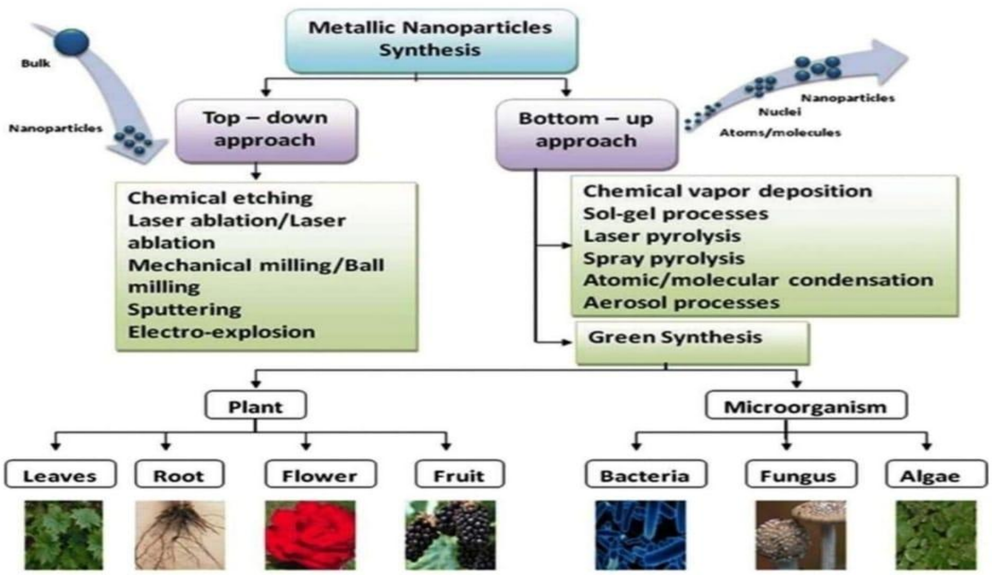
Index Terms—**Nanotechnology, drug delivery system, biochemical processes, Green methods.**

I. INTRODUCTION

Nanotechnology in drug delivery system nowadays exhibit different chemical, physical properties consequently biological effects compared to larger-scale counterparts that can be beneficial for drug delivery systems. However, the synthesis methods for NPs are hampered by the need for vacuum, exposure to radiation, and high operating temperatures which require cooling systems and expensive equipment These methods can be costly, harmful, and environmentally unfriendly. They also use toxic chemicals, stabilizing agents, and highly concentrated reductants that can be hazardous to human health and the atmosphere. Green synthesis of metallic nanoparticles offers a sustainable and environmentally benign alternative to conventional chemical methods. This approach utilizes biological entities such as plants, microorganisms, and their extracts to reduce metal precursors and cap the resulting metallic nanoparticles, thereby eliminating or minimizing the use of toxic chemicals and solvents. As per recent trend researchers are working on the green synthesis of copper oxide metallic nanoparticles and other nanostructured materials. The resulting metallic nanoparticles exhibit unique physicochemical properties tailored by the choice of biological reducing and capping agents. This abstract highlight recent advancements in green nanoparticle synthesis, including the exploration of diverse biological sources, optimization of synthesis parameters for controlled size and morphology, and characterization techniques used to confirm the formation and properties of the synthesized metallic nanoparticles. The applications of green-synthesized metallic nanoparticles in medicine, and environmental remediation, are also discussed, along with the challenges and future prospects of this rapidly evolving field, emphasizing the potential for scalable and economically viable green nanotechnology. The biochemical processes in biological agents reduce the dissolved metal ions into nano metals. Green Synthesis: The selection of a green or environmentally friendly solvent (the most widely used are water, ethanol, and their mixtures), a suitable non-toxic reducing agent, and a safe substance for stabilization are the three most important requirements for the green synthesis of NPs. Clusters of subjects continued to grow, and more interdisciplinary integration was undergoing. This study provides a systematic study of RE&SD research, and the future research of RE&SD may inevitably consider renewable energy investment and renewable energy perspective approaches to achieve sustainable development goals.

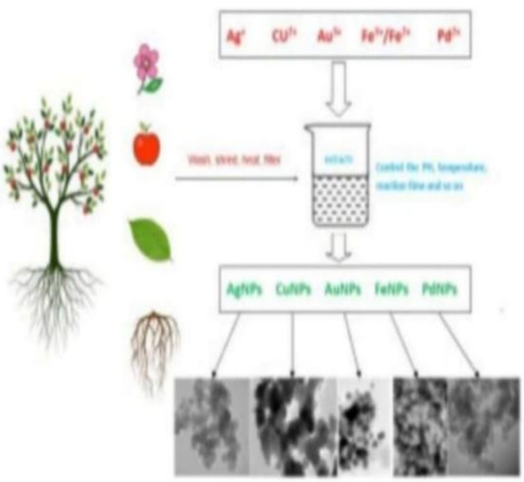
II. CLASSIFICATION

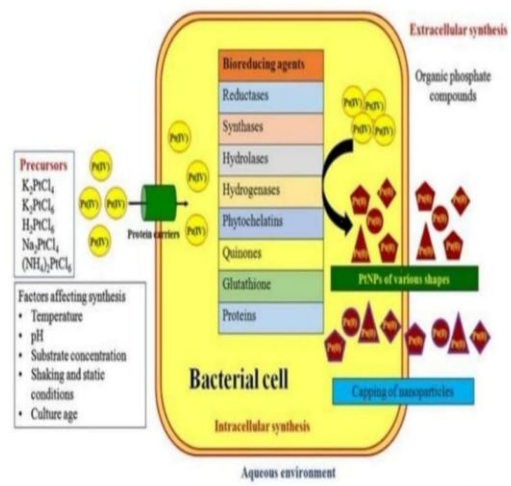
Green synthesis of metallic nanoparticles is classified based on the method used for nanoparticle formation (top-down vs. bottom-up) and the source of the biological reducing agents (plants, microbes, etc.). A top-down approach breaks down larger material, while a bottom-up approach builds from smaller components. Biological methods are a type of bottom-up approach and use eco-friendly materials like plant extracts or microorganisms to reduce metal ions. A] Classification based on the method of synthesis 1] Top-down synthesis: In this approach, a large bulk material is broken down into smaller nanoparticles. Green methods: While physical and chemical methods are traditionally used in top-down approaches, some green methods can be adapted, such as using energy-assisted techniques to break down larger precursors. Examples:Laser ablation and ball milling. 2]Bottom-up synthesis: In this approach, atoms or molecules are assembled into larger nanostructures. Green synthesis is inherently a bottom-up method. Green methods: Uses biological materials to facilitate the assembly of nanoparticles. Examples: Reacting metal salts with plant extracts or microbial cultures. B] Classification based on the source of biological agents 1] Plant-based synthesis: Uses plant extracts (like from fruits, leaves, or roots) to reduce metal ions. The polyphenolic compounds in plant extracts act as reducing and stabilizing agents. 2]Microbe-based synthesis: Employs microorganisms such as bacteria, fungi, or algae to synthesize nanoparticles. Other biological sources: Biosurfactants and enzymes can also be used as reducing and stabilizing age



Sr. No	Plant Species	Utilized Plant-Part	Types of NPs
1.	Citrus limon	Fruit-part	ZnO: TIO2
2.	Phyllanthus emblica	Fruit-part	Ag
3.	Rosmarinus officinalis	Floral-part	MgO
4.	Matricaria chamomilla	Floral-part	MgO and MnO2
5.	Matricaria chamomilla	Floral-part	ZnO
6.	Olea europaea	Leaf-part	ZnO
7.	Lycopersicon esculentum	Fruit-part	ZnO
8.	Piper nigrum	Stem-part	Ag
9.	Citrus maxima	Fruit-part	Ag
10.	Artemisia absinthium	Leaf-part	Ag
11.	Trachyspermum ammi	Leaf-part	Ni
12.	Abelmoschus esculentus	Seed-part	Au
13.	Parthenium hysterophorus	Leaf-part	ZnO
14.	Syzygium aromaticum	Bud-part	Cu

15.	Piper cubeba		Ag
16.	Nigella sativa	Leaf-part	Ag
17.	Ixera coccinea	Leaf-part	CuO
18.	Centella asiatica	-	
19.	Curcuma Longa	-	Ag
20.	Acalypha indica	Leaf-part	Ag,Au
21.	Cotyledon orbiculata	Leaf-part	Ag
22.	Cucumis prophetarum	Leaf-part	Ag
23.	Senegalia senegal	-	Ag
24.	Ocimum tenuiflorum	Leaf-part	Se
25.	Asparagus racemosus	Root	Pr
26.	Rosmarinus officinalis	Leaves	Pd
27.	Maringa oleifera	Seeds	Fe
28.	Anogeissus latifolia	Commercial Powder	Pd
29.	Cissus quadrangularis	Stem	Ag
30.	Ziziphus Mauritiana	-	Ag





Drug Profile:

Sr. No.	Aspects/Parameters	Nanoparticles	Green Nanoparticles
1.	Synthesis	Nanoparticles use hazardous chemicals and high amounts of energy for creating.	Green synthesis uses natural resources and biologically active compounds to create nanoparticles.
2.	Approach	Top down	Bottom Up
3.	**Biocompatibility**	Nanoparticles created using green synthesis are less biocompatible	Nanoparticles created using green synthesis are often more biocompatible
4.	Methods	Physical methods include vapor deposition ultraviolet radiation, aerosols and thermal decomposition, laser pyrolysis sol-gel process. chemical reduction, coprecipitation, seeding, microemulsion, hydrothermal synthesis, and sonoelectrodeposition	Synthesis using plant extract, enzyme from fungi, bacteria and virus
5.	Energy	need high temperature and pressure	Possible with low temperature and pressure Require incubator, distillation assembly

III. MATERIAL

The green synthesis of metallic nanoparticles, key materials include biological sources like plant extracts (from leaves, peels, seeds, and roots) and microorganisms (bacteria, algae, fungi). These biological materials act as both reducing and capping agents, thanks to compounds such as polyphenols and flavonoids, and are used to create an environmentally friendly process for synthesizing nanoparticles of metals like gold, silver, copper, and zinc.

1.Plant extracts:

A) Biological materials Sources:

A wide variety of for plant parts are used, including leaves, fruits, seeds, roots, and peels. Examples include fruit peels, papaya leaves, orange peels, and coffee grounds. - Function: Plant extracts contain bioactive compounds like polyphenols, flavonoids, and antioxidants, which act as reducing and stabilizing agents.

B] Microorganisms:

Sources: Bacteria, algae, and fungi can be used. - Function: Microorganisms contain enzymes and other molecules that facilitate the reduction of metal ions into nanoparticles.

C]other material:

1.Metal salt precursors : A metal salt solution (such as a silver nitrate or copper chloride solution) is the source of the metal ions that will be reduced into nanoparticles.

2.Aqueous solvent : Distilled water is commonly used to prepare the plant extracts and act as the reaction medium.

3.Nutrient broth : When using microorganisms, a sterile nutrient broth is used to culture and grow them before the synthesis reaction takes place

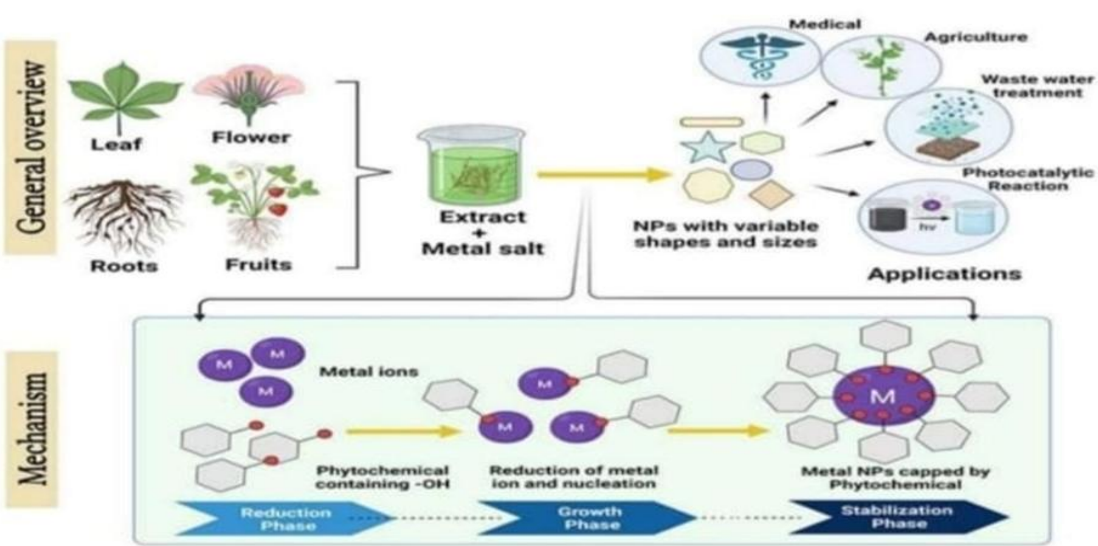
Methods of preparation: -

Green synthesis methods for metallic nanoparticles typically involve biological agents like plant extracts or microorganisms, which act as reducing and capping agents in a single step, replacing harsh chemicals. The general procedure involves combining a metal salt solution with a bio-extract, which leads to the reduction of metal ions to form nanoparticles, followed by separation and purification steps.

Common methods for green synthesis: -

A) Plant-mediated synthesis:

This is a widely used and efficient method where plant extracts are mixed with a metal salt solution. - Process: Plant extracts contain phytochemicals like flavonoids, phenols, and proteins that reduce metal ions and stabilize the newly formed nanoparticles. Steps; obtain plant extract, mix it with metal salt solution, and the bio compounds in the extract facilitate the reduction and stabilization.



B) Microorganism-mediated synthesis:
This method uses microorganisms, such as bacteria and fungi, to synthesize nanoparticles. - Process: Microorganisms are cultured in a nutrient broth containing metal ions. - Mechanism: Active molecules or enzymes produced by the microorganisms facilitate the intracellular conversion of metal ions into metal nanoparticles through an enzymatic reductionoxidation process. to steps; Culture the microorganism, harvest and purify it, and then add the metal ion solution promote the synthesis of nanoparticles.

IV. APPLICATION OF GREEN METALLIC NANOPARTICLES

♣ Green metallic nanoparticles have a broad spectrum of applications across several industries. In biomedicine, the rising concern over microbial resistance to antibiotics and the emergence of resistant strains have driven significant interest in the antimicrobial properties of metallic nanoparticles.
♣ oThese nanoparticles, synthesized through green methods, have demonstrated potential as effective agents in combating resistant bacteria.
♣ Additionally, nanoparticles from sources such as blueberry, turmeric, and pomegranate have been shown to offer antioxidant benefits and play a role in cancer management.
♣ Gold and silver nanoparticles derived from various sources have particularly promising outcomes in breast cancer therapy.

A) In environmental remediation
green metallic nanoparticles have been used in water recycling systems, with platinum nanoparticles (Pt NPs) serving as catalysts in water treatment processes. These nanoparticles can be reused multiple times, maintaining approximately 83% of their original efficiency. This property makes them a sustainable and efficient solution for environmental applications.

B) In the agriculture sector,
green nanoparticles, especially silver nanoparticles (Ag NPs), have demonstrated positive effects on seed germination, plant growth, development, and gas exchange rates, particularly under various abiotic stresses. This suggests that green metallic nanoparticles can play a role in enhancing agricultural productivity and resilience.

Advantages of Green Nanoparticle Synthesis

- Clean and eco-friendly approach, as toxic chemicals are not used.
- The active biological component itself acts as capping and reducing agent, therefore reduction the overall cost of synthesis process.
- Can be used at large scale of nanoparticles. iv External experimental conditions like high energy

and high pressure are not required, leads to energy saving process.

Disadvantages of Green Nanoparticles Synthesis

I. Plants cannot be manipulated as the choice of nanoparticles through optimized synthesis through genetic engineering.
II. Plant produces low yield of secreted proteins which decreases the synthesis rate.
III. Culturing of micro-organisms is time-consuming.
IV. Difficult to have control over size, shape and crystallinity. Particles are not mono-dispersed and rate of production is slow.

V. SCOPE & CHALLENGES

♠ Despite its promising benefits, there are challenges associated with the green synthesis of nanoparticles. Safety concerns related to the potential toxicity of nanoparticles are a significant issue. Nanoparticles can pose health risks, especially if not carefully regulated, which necessitates thorough research to ensure their safety in various applications, particularly in biomedicine and agriculture.

♠ High costs associated with the development of nanobiotechnology products can limit the ability of smaller players to enter the market. The initial investment in research, development, and production facilities can be substantial, creating a barrier to entry for new companies.

♠ Furthermore, the regulatory hurdles faced by nanotechnology products are considerable.

♠ Stringent regulations for the approval and commercialization of new nano-based products can slow down the process of bringing innovations to market. As a result, it may take longer for new green nanoparticle-based technologies to be widely adopted.

VI. CONCLUSION

In conclusion, the green synthesis of metallic nanoparticles is a rapidly advancing field with considerable potential in areas such as environmental remediation, biomedicine, and agriculture. While there are challenges related to safety, cost, and regulatory approval, the advantages of using renewable resources, eco-friendly solvents, and non-toxic agents in the synthesis process offer promising solutions for sustainable nanomaterial production. Ongoing research and development in this area will likely continue to address these challenges, paving the way for the widespread application of green metallic nanoparticles in diverse

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