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An Overview on Green Synthesis of Nanoparticles for Sustainable Future

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Abstract: **Biological approaches seem to be the perfect options for the massive-scale manufacturing of nanoparticles. In recent years, the development of efficient green chemistry methods for the synthesis of metal nanoparticles has become an excellent element for researchers. Researchers studied an ecologically sustainable method of producing nanoparticles. Microorganisms are generally used to produce metal nanoparticles. Nanoparticles obtained from plants are more stable than nanoparticles produced by microorganisms. However, the nanoparticles are not the same form or size as those produced by other species.**

This paper discusses green synthesis methodologies for nanoparticles as well as their variety of applications. It gives a collation of effective techniques of synthesis using green routes compared to other techniques, which is excellent confirmation for choosing the optimal methods for the manufacturing of nanoparticles.

Keywords: Biosynthesis, eco-friendly, sustainable, green synthesis, nanoparticles

INTRODUCTION:

Paul Anastas is the “Father of Green Chemistry” and is widely known for his revolutionary research on the development, manufacture, and application of non-toxic materials for a pollution-free environment. The chemical community must undergo a major shift to achieve sustainable chemistry. Green chemistry principles must be included in part of teaching and practice in chemistry[1].

The nanoscale material ranges from one to a hundred nanometers used in a new area of nanoscience. They have the potential to solve problems in branches such as water treatment, catalysis, solar energy conversion, medicine. This growing demand must be fulfilled using "green" technology. The proclivity to recycle waste improves the overall environmental friendliness of the process. As a result, the method is particularly appealing due to its simplicity, as the reaction is completed in 10 minutes and no organic solvent is required at any stage of the process (1). "Green" chemistry and chemical processes are gradually integrating with modern scientific and industrial developments in the global effort to reduce hazardous waste. The implementation of these sustainable processes should adhere to the 12 fundamental principles of green chemistry[3].

Following are the Green Chemistry consists of 12 principles that can be applied to almost any aspect of chemistry, along with the synthesis of molecules with the appropriate structure and properties, process catalysis, less polluting reaction conditions, and so on.

1. Prevention: The prevention of waste formation.
2. Less toxic substance synthesis: Synthetic methods should be designed to use and produce substances that are safe for human health and the environment.
3. Before Chemicals: Chemical products should be designed to perform their intended function while remaining as non-toxic as possible.
4. Atom economy: Synthetic procedures should be designed to use as few materials as possible in the end result.
5.Safer chemical design is advantage of green synthesis.
6.Energy efficiency is possible in this.
7. Use renewable feedstock: Where technically feasible, raw materials or feedstock should be renewable rather than depleting.

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Diagram1: Twelve Principles of green synthesis.

8. Lessen derivatives: If possible, unnecessary derivatization (use of blocking groups, protection/deprotection/deprotection, and temporary modification of physical/chemical/chemical processes) should be reduced or avoided, as such steps require additional reagents and can generate waste.

9.Catalysis : Catalysis: Selective catalytic reagents outperform stoichiometric reagents. The use of catalytic reagents allows for greater selectivity, higher yield, and the possibility of previously infeasible reactions.

10. Design for degradability: Chemical products should be designed so that when they no longer serve their purpose, they degrade into innocuous degradation products and do not persist in the environment.

11. Real-time pollution prevention analysis: Analytical methodologies must be improved to allow for real-time pollution prevention analysis.
2. Inherently safer for accident prevention: Substances and the form of a substance used in a chemical process should be preferred to reduce the possibility of chemical accidents such as releases, explosions, and fires.

APPROCHES OF NANOPARTICLE SYNTHESIS:

At the moment, the top-down and bottom-up approaches to nanoparticle synthesis are the two most popular. By breaking down the bulk material, the top-down approach produces nanoparticles. In contrast, the bottom-up approach creates nanoparticles through chemical reactions between atoms and/or molecules. Green methods have been shown in studies to be more effective for the generation of NPs due

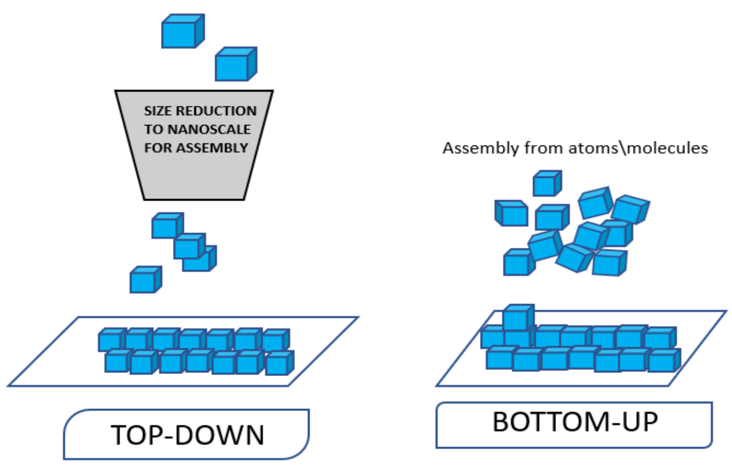

Diagram 2: Approaches of green synthesis.

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to lower failure rates, lower to costs, and characterization is made simple. The pH of the solution, temperature, extract concentrations, raw material concentrations, size, and, most importantly, synthesis methods must all be taken into account. Despite the many advantages of organic green synthesis, controlling NP polydispersity is a significant challenge. Optimize the reaction conditions by adjusting the pH, temperature, incubation time, irradiation, salt concentration, and redox state to tackle this issue. pH is a significant consideration in the environmentally friendly synthesis of nanoparticles. In the case of plants, pH changes affect the phytochemical charge, which affects reduction and biding during the synthesis process. Green technology is used to synthesize nanoparticles at temperatures below 100 ° C. Furthermore, particle size and porosity influence the properties of green nanoparticle synthesis. Green synthesised nanoparticles have attracted the attentions of many people due to their inherent characteristics such as speed, eco-friendliness, and cost-effectiveness. 6. The green synthesis of NPs entails three major steps that must be evaluated from the standpoint of green chemistry, namely
(1) selection of solvent medium,
(2) selection of solvent medium, and
(3) selection of solvent medium[7].
A. Physical synthesis of nanoparticles: Thermolysis, Fusion Blending, Laser Ablation, Implantation of ions, sputtering deposition, electric arc deposition and other physical processes are used to produce nanoparticles[8].Microwave-assisted synthesis: Microwave-assisted reactions were carried out in a domestic microwave at atmospheric pressure[9].

B. Chemical synthesis is among the most widely used methods for producing large quantities of nanoparticles in a short amount of time. The disadvantages are the high toxicity of the chemical synthesis and the high cost of the chemicals used10.[10]
C. Biological synthesis:

SYNTHESIS OF NPS FROM PLANT EXTRACT:

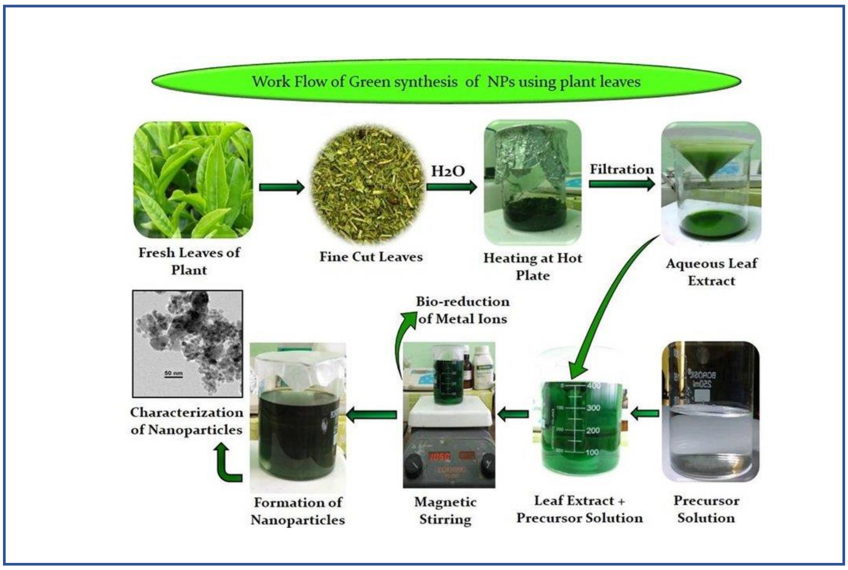

Diagram 3: Work flow of green synthesis of NPs using plant leaves.

Plant extract preparation: The plant's fresh leaves to be used were collected. The leaves were thoroughly washed and dried. After powdering the dried leaves with a mortar, 20 g of powdered leaves were mixed with 200 mL deionized water and heated at 80°C for 10 minutes with a heater-stirrer. The mixture was filtered and centrifuged after the plant residue and impurities were removed before being stored for future use.

Table 1: Plant source for nanoparticle synthesis

Sr.no.	Plant extract	Part used	Precursors	Shape	Size	Reference
1	Sophora japonica	Pods	$Na_2S_2O_3$	Spherical	60nm	(3)
2	Azadirachta Indica	Leaves	$Ca(NO)_3$	Star	50nm	(4)
3	Plantago major	Leaves	$AgNO_3$(5)	Spherical	12-18nm	(6)
4	Citrus limon	Fruits	$AgNO_3$	Spherical	-	(7)
5	Tea	Leaves	$Ca(NO_3)_2.4H_2O$	Agglomerated	86-117nm	(8)
6	Papaya	Leaves	$Ca(NO_3)_2.4H_2O$	Agglomerated	89-180nm	(9)
7	Oscimum sanctum	Leaves	$Ca(NO_3)_2$	Needle	-	(10)
8	Piper betle L.	Leaves	$AgNO_3$	NA	37	(11)
9	Plumeria rubra L.	Leaves	$AgNO_3$	NA	32	(12)
10	Piper nigrum L.	Leaves	$AgNO_3$	spherical	50	(13)
11	Solanum xanthocarpum L	Leaves	$AgNO_3$	NA	10	(14)
12	Sorghum	Leaves	$AgNO_3$	NA	10	(15)

13	Swietenia mahogany L.	Leaves	$AgNO_3$	NA	10-35	(16)
14	Trianthema decandra L.	Leaves	$AgNO_3$	NA	10-50	(17)
15	Tridax procumbens L.	Leaves	CuO_2	NA	NA	(18)
16	Zingiber officinale	Rhizome	$AgNO_3$	spherical	10	(19)
17	Vitis vinifera grape	Fruits	AgNO	spherical	NA	(20)
18	Euphorbia condylocarpa M.	Fruits	$PdCl_2$	NA	NA	(21)
19	Manilkara zapota	Leaves	$AgNO_3$	spherical	NA	(2)

This plant contains a variety of bioactive compounds, such as alkaloids, fatty acids, flavonoids, terpenoids, phenolic acid derivatives, vitamins, and others, which contribute to its specific therapeutic effects (6).

b. Synthesis of NPs from microorganisms: nanoparticles are synthesized using bacteria, fungi, algae.

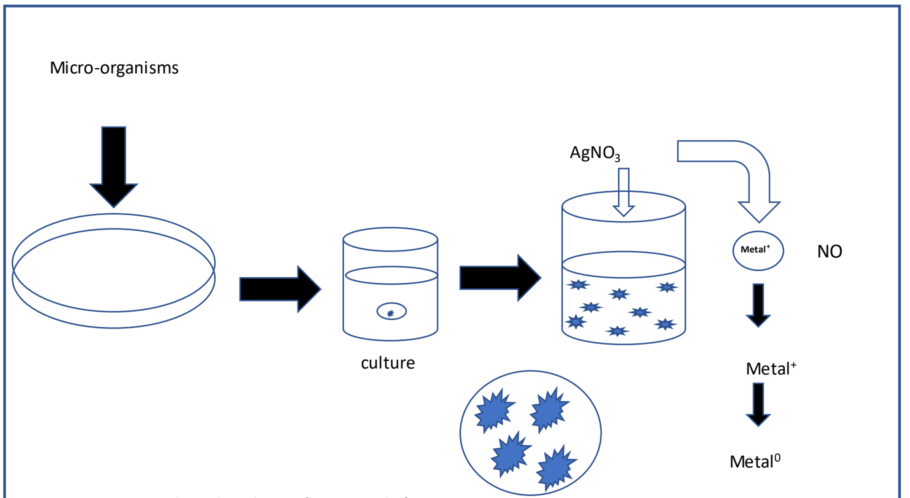

Diagram2: Biological synthesis of nanoparticle from MOS.

Table 2: Fungi source for nanoparticle synthesis

Sr.no.	Fungi	NP	Location	Shape	Size	Reference
1	Shewanella oneidensis	Au	Extracellular	spherical	12 ± 5	(22)
2	Aspergillus niger	Ag	NA	spherical	20	(23)
3	Aspergillus oryzae	Ag	NA	NA	5-50	(24)
4	*Fusarium oxysporum*	Ag	Extracellular	spherical	1	(25)
5	Klebsiella pneumoniae	Se	NA	spherical	100	(26)
6	Phaenerochaete chrysosporium	Ag	Extracellular	NA	50	(27)
7	Trichoderma asperellum	Ag	Extracellular	NA	13-18	(27)
8	Fusarium oxysporum	$PbCO_3$	Extracellular	spherical	120–200	(28)
9	Fusarium semitectum	Ag	NA	NA	NA	(29)
10	Phaenerochaete chrysosporium	Ag	NA	NA	NA	(30)
11	Aspergilus terreus	Ag	Extracellular	spherical	20	(31)
12	Yarrowia lipolytica	Au	Extracellular	Triangles	15	(32)
13	V. luteoalbum	Au	Intracellular	NA	NA	(32)
14	Candida utilis	Au	Intracellular	NA	NA	(33)

The following are the drawbacks of microbial nanoparticle synthesis:

1.The requirement for isolation rooms and long-term maintainance in terms of protecting microorganism growth. Controlling the size, shape, and crystallization of nanoparticles poses great challenges.

2. Manipulation of reaction parameters such as pH and temperature may interfere with microbial growth and biological induction procedures. When working with bacteria by hand, the user must take extra precautions.

3.Biosafety issues should be addressed in microbiological research, large-scale nanoparticle microorganisms, and commercial applications. Nanomaterials have the potential to cause human harm or to spread dangerous bacterial diseases (34).

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Table 3: Bacterial source for nanoparticle synthesis

Sr.no.	Bacteria	NP	Location	shape	Size	Reference
1	Escherichia coli	Cds	NA	NA	NA	(35)
2	Pseudomonas stutzeri	Ag	Intracellular	NA	~200	(36)
3	Lactobacillus strains	Ag, Au	NA	NA	15-40	(37)
4	Corynebacterium Ag NA 5/15 NA	Ag	NA	NA	5-15	(38)
5	Staphylococcus aureus	Ag	NA	NA	150-180	(39)
6	Ureibacillus thermosphaericus	Ag	NA	NA	1-100	(40)
7	Clostridium thermoaceticum	CdS	Intracellular and extracellular	NA	NA	(41)
8	Rhodopseudomonas capsulata	Au	Extracellular	spherical	10-20	(42)
9	Aspergilus turrets	Ag	Extracellular	spherical	1-20	(31)
10	Bacillus licheniformis	Ag	Extracellular	Spherical	23	(30)
11	Schizosaccharomyces pombe	CdS	Extracellular	Hexagonal lattice	1–1.5	(43)
12	Schizosaccharomyces pombe and candida glabrata	CdS	Intracellular	Hexagonal lattice	2	(44)
13	pseudomonas sp.	Au	Extracellular	Spherical	10	(42)
14	Brevibacterium casei	Au	Intracellular	Spherical	10-20	(29)
15	Enterobacter sp.	Hg	Intracellular	Spherical	2-5	(45)

CHARACTERIZATION OF NPS:

Scanning electron microscopy (SEM), atomic force microscopy (AFM), X-ray diffraction (XRD), fourier transform infrared spectroscopy (FT-IR), transmission electron microscopy (TEM), energy dispersive spectroscopy (EDS), and dynamic light scattering were used to characterise the samples (DLS).

a. UV-vis spectrophotometry :

Light frequencies ranging from 200–800 nm are commonly used .To characterize NPs, UV-vis absorption measurements at wavelengths ranging from 250 to 400 nm are used.

b. XRD:

XRD is a valuable technique for understanding the atomic and crystal structure of nanomaterials. analysing XRD is a useful characterization tool for validating NP formation, evaluating crystal structure and planes, and determining the size of crystalline NPs. The standard JCPDS (Joint Committee on Powder Diffraction Standards) papers were used for NP confirmation.

c. FT-IR:

FT-IR is a type of molecular spectroscopy that examines different chemical functional groups in the 400 to 4000 cm-1 range.

d. SEM:

A fundamental analysis approach that generates a micro-image as an output using electrons rather of light. The polydispersity and purity of the resultant NPs are shown in SEM microphotographs.

e. TEM:

TEM is a significant characterization technique that allows you to evaluate a material's particle size on a nano-scale and thoroughly examine the crystal structure with high resolution. TEM analyses are carried to estimate the average size of NPs and size distribution. (46) .

APPLICATIONS OF GREEN NANOTECHNOLOGY:

1. Green-synthesized nanoparticles have clinical applications. When silver nanoparticles were treated against S. aureus, their antibacterial activity was at its peak.
2. Nanoparticles used as drug carriers are highly stable, can incorporate both hydrophobic and hydrophilic substances, and can be delivered via a variety of routes also including oral application and inhalation.
3. Applications in healthcare:
a. Dental adhesives
b. Burn to heal and wound care
c. Skin therapy
d. Bone cements and reconstructive orthopaedics
e. Medical devices and catheters made of plastic
f. Targeted drug administration
g. Medical imaging, biomarker detection
h. Cancer treatment
i. breath mask coating intellectual property rights and ultrasonic detection, Implant coating for joint replacement.
5. Fungicidal activity: NPs have antifungal and fungicidal activity against Candida albicans, Candida krusei, Candida species, Candida glabrata, Trichophyton mentagrophytes, and Candida tropicali.

6. Antibacterial activity: NPs inhibit Gram positive and Gram negative bacteria, as well as Pseudomonas aeruginosa, Bacillus cereus, Escherichia hermanii, Bacillus subtilis, Klebsiella pneumonia, agricultural plant pathogens, and antibiotic-resistant bacteria.

7. Antiviral activity: NPs has antiviral activity against human immunodeficiency virus-1, influenza virus (HIV-1), herpes simplex virus, herpes simplex virus, herpes simplex virus, herpes simplex virus, monkeypox virus, hepatitis B, HSV-1, and respiratory syncytial virus.

Table 4: Applications of NPs synthesized by green synthesis

Sr. no.	Name of plant	Application	Reference
1	Alianthus altissima	Seed germination study	(47)
2	Allium sativum	Antifungal activity	(47)
3	Azadirachta indica	Antibacterial activity	(47)
s4	Oscimum basilicum	Seed germination study	(48)
5	Punica granatum	Foliar spray	(49)

FUTURE PERSPECTIVE:

Green nanotechnology is a rapidly evolving approach with applications in all aspects of life for the creation of innovative, reliable, and long-term solutions. By efficiently tackling the inherent limitations, this green technology has the potential to assist future generations in all sectors of life. On a daily basis, astonishing in the field of nanoparticle synthesis and their sophisticated applications in the huge venue of science and technology are occurring in this era of nanotechnology.

CONCLUSION:

The use of biological sources such as organisms and plants can aid in the reliable and ecologically sustainable synthesis of nanoparticles. The synthesis of nanoparticles by these natural sources is characterized by processes that take place at near-ambient temperatures and pressures, as well as near-neutral pH . The current review study incorporates current knowledge and develops a database of natural decomposition agents for various nanoparticles using various biological systems. As a result, choosing an appropriate biological element for large-scale, environmentally acceptable commercial production of nanoparticles is crucial. Simple, cost-effective, environmentally friendly, and easily scalable procedures, as well as parameters for controlling the size and shape of the materials, should be established. Recognizing the biological system's full capacity is crucial.

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