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Temple Waste to Nanoparticles: Green Synthesis of Nanoparticles Using Discarded Temple Flowers, Leaves and Sacred Tree Residues

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***Abstract*—The uses of flower and plant-based extracts for the production of nanoparticles is known as green synthesis, and it has rapidly emerged as one of the most compelling and eco-conscious alternatives to conventional, energy-intensive chemical and physical methods. Our focus here is on an innovative path forward for using temple flowers, leaf waste and sacred trees residues biomass that is a major waste stream to establish an 'Eco-Friendly Nanotechnological Synthesis' route that directly resolves issues of resource strain and waste overload.**

This review highlights the diverse botanical sources including jasmine flower, Hibiscus flowers and leaves, Ocimum species, Tagetes erecta, Clitoria ternatea flower , Rose petals, Plumeria alba, Lotus, Piper betel , Aegla Marmelos leaf , Datura, Pinwheel flower, Durva grass, Ficus religiosa and many other temple and flower west used for the biosynthesis of metal and metal oxide nanoparticles, such as silver AgNPs, Copper CuNPs, Gold AuNPs, Platinum PtNPs, Zinc ZnNPs, Cobalt CoNPs , Magnesium MgO nanoparticles, Lantham La_2O_3 and Hematite Fe_2O_3 nanoparticles. This flower and plant extracts are rich in phytochemicals that do the, crucial work of acting as a natural reducing, capping, and stabilize agents, make possible nanoparticles creation under ambient conditions without producing toxic byproducts. Green Synthesis has emerged as a sustainable method for making metallic nanoparticles. The resulting nanoparticles show varied sizes and shapes and possess notable antioxidant, antimicrobial, and catalytic properties. This paper ultimately underscores the immense potential of floral; leaf and scared trees residues extracts in developing cost-effective, biocompatible nanomaterials for various biomedical, environmental and industrial application.

I. INTRODUCTION

Green nanotechnology, which uses biological resources for synthesis of nanoparticles, represents a major shift away from traditional chemical methods that are often costly and toxic. This approach relies on the bio-reduction ability of phytochemicals present in plant and flower extracts. The rich variety of these phytochemicals make plants a highly suitable and sustainable sources for producing metallic nanoparticles [3].

The core focus of this review is the use of temple flowers (such as rose, jasmine, hibiscus rosa, marigold) and other plants waste biomass. It is important to note that the large quantities of temple flower, plant and sacred trees waste are generated daily at religious sites, and in many cases, these wastes are directly thrown into rivers, lakes, and natural water bodies and this is creating a serious environmental challenge [7]. By harnessing the extracts from this biomass, researchers have unlocked and economical and sustainable resource for NP synthesis not only offer an eco-friendly solution but also helps address this waste disposal problem. This approach fully aligns with the principles of green chemistry and supports the development of a truly eco-friendly nanotechnological synthesis route [1].

II. PHYTOCHEMICAL COMPOSITION AND MECHANISM

Phytochemical analysis shows that extracts prepared from temple flower and plant wastes naturally contain a wide range of bioactive molecules such as flavonoids, polyphenols, tannins, and alkaloids. These plant-based compounds play two important roles during nanoparticles formation [8].

As reducing agents:

The crucial function of the phytochemicals is to drive the bio reduction process, facilitating the conversion of metal ions like Ag^+, Au^{3+}, Fe^{3+} and Cu^{2+} directly into their respective Zero-valent nanoparticles forms [2]. For example, phytochemicals present in Ocimum sanctum (Tulsi leaf), Plumeria spp. (Champa) and Piper beetle extracts have been reported to work as excellent natural reducers for the synthesis of metal nanoparticles [9]-[12].

As capping/stabilizing agents:
Once the nanoparticles are formed, these compounds attach to their surface and create a thin protective layer. This coating prevents the particles from sticking together and ensures the long-term stability of the nanoparticles [1, 6].

III. GREEN SYNTHESIS OF SPECIFIC NANOPARTICLES

Table 1: Summary of reported studies on green synthesis of nanoparticles using common temple flower and leaf waste

No.	Flower /Leaf Source	Scientific name	Metal ion used	Metal salt/ Chemical	Color change during synthesis	Type of nanoparticle formed	Key role of plant extract	Citation
1	Aparajita	Clitoria ternatea	Zinc oxide (ZnO)	Zinc salt	Light blue-White	ZnONPs	Anthocyanins act as strong reducers	[6], [13]
2	Galgota (Marigold)	Tagetes erecta	Silver (Ag)	$AgNO_3$	Yellow-Brown	AgNPs	Contains flavonoids and terpenes	[14], [15]
			Cadmium (Cd)	$CdCl_2$	Dark yellow-Off white/Pale yellow	CdNPs	Contain flavonoids, terpenoids, phenolic	[2]
3	Jasud	Hibiscus Rosa	Copper (Cu)	$CuSO_4$	Blue-Greenish brown	CuNPs	Anthocyanins help reduction, saponins, tannin	[2], [6], [8], [16]
			Ferric oxide (Fe_2O_3)	$FeCl_3$	Dark brown-Reddish brown	Fe_2O_3NPs		
			Silver (Ag)	$AgNO_3$	colourless-Dark brown	AgNPs		
			Gold (Au)	$HAuCl_4$	Pale yellow-Red	AuNPs		
			Zinc oxide (ZnO)	Zinc salt	Pink-Off white	ZnONPs		

4	Rose	Rosa indica	Gold (Au)	$HAuCl_4$	Yellow-Ruby red	AuNPs	Rich in tannins and phenolics	[17], [18], [19]
			Silver (Ag)	$AgNO_3$	Colorless -Dark brown	AgNPs		
			Cobalt (Co)	$Co(NO_3)_2$	Dark brown-Greyish black	CuNPs		
5	Champa	Plumeria alba	Silver (Ag)	$AgNO_3$	Colorless –Brown	AgNPs	Contains alkaloids, Saponins and essential oils	[2], [10]
			Gold (Au)	$HAuCl_4$	Yellow-Red	AuNPs		
6	Lotus	Nelumbo nucifera	Silver (Ag)	$AgNO_3$	Colorless -Dark brown	AgNPs	Polyphenols promote reduction	[20]
7	Jasmine (Mogra)	Jasminum sambac	Silver (Ag)	$AgNO_3$	Colorless -Dark brown	AgNPs	Aromatic Phenols stabilize nanoparticles	[21], [22], [23]
			Copper (Cu)	$CuSO_4$	Blue-Brown	CuNPs		
9	Tulsi leaf	Ocimum sanctum	Silver (Ag)	$AgNO_3$	Pale yellow-Dark brown	AgNPs	Eugenol and flavonoids act as capping agents	[9], [11], [24], [25], [26]
			Zinc oxide (ZnO)	$Zn(OAc)_2$	White	ZnONPs		
			Platinum (Pt)	H_2PtCl_6	Pale yellow-Dark brown	PtNPs		
			Copper (Cu)	$CuSO_4$	Blue-Dark brown	CuNPs		
10	Bilva patra	Aegla marmelos	Silver (Ag)	$AgNO_3$	Colorless -Dark brown	AgNPs	Tannins and terpenoids	[1], [27], [28]

			Gold (Au)	$HAuCl_4$	Red color	AuNPs	act as reducer	
			Fe_3O4	$FeSO_4/FeCl_3$	Green-Black	Fe_3O4NPs		
11	Betel leaf (Pan)	Piper betle	Gold (Au)	$HAuCl_4$	Red-Purple	AuNPs	Polyphenols aid reduction	[12]
12	Neem Leaf	Azadirachta indica	Silver (Ag)	$AgNO_3$	Colorless -Brown	AgNPs	Well known reducing and stabilizing agents	[9], [28], [29]
			Ferric oxide (Fe_2O_3)	$FeCl_3$	Dark brown-reddish brown	Fe_2O_3NPs		
			Gold (Au)	$HAuCl_4$	Red-Purple	AuNPs		
13	Mango leaf	Mangifera indica	Silver (Ag)	$AgNO_3$	Colorless -Brown	AgNPs	Polyphenolic antioxidants	[30]
14	Peepal leaf	Ficus religiosa	Lanthanum (La_2O3)	$La (NO3)_2$	Greenish brown-White	La_2O3 NPs	Natural antioxidants and stabilizer	[31]
			Cerium oxide (CeO_2)	$Ce (NO_3)_3$	Pale yellow	CeO_2 NPs		
15.	Datura	Datura stramonium	Magnesium Oxide (MgO)	$Mg (NO_3)_2$	Colorless -White	MgO NPs	Promising antibacterial activity	[32]
16.	Vad	Ficus Benghalensis	Gold (Au)	$HAuCl_4$	Red-Purple	AuNPs	Promising antibacterial activity	[33]
17.	Pinwheel flower	Tabernaemontana divaricata	Zinc oxide (ZnO)	$Zn (NO_3)_2$ /$Zn (OAc)_2$	Colorless -White	ZnONPs	Contain Flavonoids, phenolic and alkaloids	[34]
18	Durva grass	Cynodon dactylon	Gold (Au)	$HAuCl_4$	Ruby red	AuNPs	Polyphenols, flavonoids act as reducing and capping agent	[35], [36]
			Zirconia (ZrO_2)	$ZrOCl_2$	White	ZrO_2 NPs		

19	Kaner flower	Nerium Oleander Flower	Ferric oxide (Fe_2O_3)	$FeCl_3$	Brown	Fe_2O_3NPs	Contain flavonoids, phenolic compound act as reducing & capping agent	[37]

IV. GENERAL METHOD FOR GREEN SYNTHESIS OF NANOPARTICLES (AS REPORTED IN LITERATURE)

Various researcher has reported the green synthesis of metal nanoparticles using different temple flower and leaf extracts. The overall procedure commonly includes the following step:

Preparation of plant and flower extract (Reported in literature)
Temple flower and leaf are washed and dry then boiled in distilled water to extract the phytochemicals. The mixture is filtered to obtain a clear aqueous extract rich in flavonoids, tannins, phenolics, alkaloids and other biomolecules.

Preparation of Metal salt solution
Researchers use aqueous solution of metal salt such as silver nitrate ($AgNO_3$), Copper sulfate ($CuSO_4$), Zinc sulfate or Zinc nitrate ($ZnSO_4$ / Zn $(NO_3)_2$, Ferric chloride ($FeCl_3$) and chloroauric acid ($HAuCl_4$) and many others (give in table no 1) with concentrations typically ranging between 1-10 mM [1]-[37].
Reduction and formation of nanoparticles
When the flowers and plants extract is mixed with the metal salt solution, phytochemicals present in the extract act as natural reducing agents and convert the metal ions into nanoparticles. A characteristic color change is commonly observed indicating the formation of nanoparticles [1]-[37].

V. CHARACTERIZATION TECHNIQUES OF BIOGENIC NANOPARTICLES

The efficacy and true scientific value of any synthesized nanoparticles are dictated not only by its creation but by its subsequent, rigorous characterization.[1] Since plant extracts contain a complex mixture of biomolecules, it is crucial to employ various analytical techniques to confirm that the desired metallic nanoparticles (MNPs) have been successfully formed and to understand their properties. These techniques allow scientists to precisely determine the size, shape, crystal structure, and surface chemistry of biogenic nanoparticles, which directly influence their applications in fields like catalysis and biomedicine [2, 6, 7, 10].
The primary techniques utilized in the relevant literature for resolving the physicochemical properties of materials are detailed in table 2

.

Table 2. Summary of reported studies on essential characterization techniques for green synthesized nanoparticles.

Technique Name	What measures	Key findings determined	Example reference
Uv-Visible spectroscopy	The initial confirmation of successful MNPs formation is often achieved via UV-Visible spectroscopy. This method is crucial for observing the characteristic surface plasmon resonance (SPR) band, which definitively validates the reduction of the metal ions and provides a first assessment of stability	Confirmative of synthesis and stability (e.g., AgNPs show a peak around 400-450 nm)	[3]

Transmission electron microscopy (TEM)/Scanning electron microscopy (SEM)	High resolution imaging, primarily achieved through TEM and SEM, is indispensable for resolving the morphological attributes of the materials. These techniques precisely elucidate the particle shape (e.g., spherical, anisotropic) and quantify the average particle size.	Shape (spherical, rod like, etc..) and average size (in nanometers)	[2]
X-ray diffraction (XRD)	Structural analysis hinges on X-ray diffraction (XRD). This technique actively determines the material's crystallinity and identifies its unique crystal phase (e.g., face centered cubic). Furthermore, XRD data is essential for calculating the crystallite the Debye Scherrer equation.	Crystal structure (e.g., Face centered cubic FCC, purity, and precise size calculation.	[3]
Fourier transform Infrared spectroscopy (FTIR)	The Surface chemistry detector: - Check which organic molecules from the plant and flower extract are stuck to nanoparticle surface.	Identification of capping/stabilizing biomolecules (e.g., proteins or phenols) that prevent NPs from clumping together.	[1]
Energy dispersive X-ray analysis (EDX/EDS)	Elemental analyzer: - Determines the chemical elements present in the sample	Qualitative and quantitative confirmation of the metallic element (e.g., Silver, copper) and its purity.	[3]

VI. APPLICATIONS OF BIOGENIC NANOPARTICLES

The nanoparticles synthesized using temple waste (flower, leaves, scared tree leaf) extracts demonstrate a broad spectrum of promising application:

Antimicrobial and biomedical

- AgNPs and CuNPs are highly effective pathogens.
- AgNPs derived from Ocimum sanctum exhibited robust activity even against drug resistant bacterial strains, underscoring the extracts synergistic power [9, 25].
- AgNPs synthesized from Aegle marmelos showed antimicrobial, antioxidant, and anticancer activity [27].
- ZnO nanoparticles derived from Ocimum basilicum, floral waste, clitoria ternatea and tabernaemontanadivaricata extract exhibited potent antibacterial activity [6, 13, 24, 34].
- Rosa centifolia mediated AgNPs showed activity against drug resistant bacteria.[19]

Catalysis

- In terms of environmental remediation, the resultant biogenic AgNPs and PtNPs have repeatedly proven to be highly efficient catalysts [2].
- The PtNPs synthesized via Aegle marmelos leaves, and Hibiscus rosa sinensis leaves, for example, offer a significant cost advantage over traditional platinum catalysts [1, 16].

Antioxidant activity

- A compelling benefit of the green synthesis route is that many resultant nanoparticles, particularly those from Rosa canina and Tagetes erecta, successfully inherited and retain the potent inherent antioxidant capacity of parent plant, making them highly desirable candidates for therapeutic drug delivery and formulation [5, 15].

VII. CONCLUSION

flowers, plant wastes and sacred temple tree waste biomass as a sustainable, non-toxic route for making metallic nanoparticles (MNPs). This innovation approach not only offers an economical and eco-friendly alternative to conventional synthetic methods but also plays a key role of effective waste management strategies [3].

The resulting biogenic nanoparticles have demonstrated broad applicability, particularly in the antimicrobial, antioxidant, and catalytic fields [24, 26]. Despite these favorable results, future research must concentrate on optimizing reaction parameters to achieve scalable, reproducible synthesis and further exploration of novel, high value applications for this sustainable class of nanomaterials [3].

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