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Plant Mediated Green Synthesis of Metallic Nanoparticles and its Biomedical Applications

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Abstract: ***Nanoparticles (NPs) synthesized by green techniques have received reseachers attention due to their unique physicochemical characteristics and their immense applications in various field. In recent years, synthesis of metal nanoparticles (MNPs) by green technique using plant extracts has become centre of attraction researchers because these NPs have low hazardous effect on the environment and also low toxicity for the human body.***

The plant extract contains various secondary metabolites which act as a reducing and stabilizing for various metallic nanoparticles synthesis.

The non-biological methods i.e. the conventional chemical and physical methods are highly toxic and have serious hazardous effect on human beings and other organisms. On the other hand, the biological or green synthesis of metallic nanoparticles is less expensive, single step process, eco-friendly and also shows effective result. Different plant extracts has been used successfully with various metallic nanoparticles such as, copper, silver, gold, palladium, platinum and zinc oxide. Also, these nanoparticles have potential to cure many diseases such as cancer, hepatitis, malaria, and other deadly diseases. This paper presents a review on plant mediated synthesis of metallic nanoparticles by green technology.

Keywords: Nanoparticles, plant mediated synthesis, Green technology, plant extracts, biological synthesis

I. INTRODUCTION

Nanotechnology is an advanced and emerging technology with extensive fields of applications like electronics, optics, mechanics, non-linear optical devices, cosmetics, coatings, packaging, biomedical, drug delivery, gene delivery, tissue engineering, health care , food industry, space industry etc.

Nanoparticles are generally very small in size, ranges from 1-100 nm. Because of their improved thermal conductivity, catalytic reactivity, nonlinear optical performance, and chemical stability due to their large surface area-to-volume ratio, they possess immense applications in various fields.

In the last few decades, metal nanoparticles (MNPs) like TiO_2, CaO, CuO, ZnO etc have attracted many researchers as MNPs have immense applications in various fields because of their distinct physical, chemical and biological properties.One of these is Calcium Oxide nanoparticle (CaO NPs), which is an inorganic metal oxide nanoparticles possess multifunctional properties , are stable and also safe to environment. These unique characteristics of CaO NPs have attracted researchers to locate novel techniques to their synthesis [1, 2, 5].

There are various conventional methods for synthesis of nanoparticles such as physical and chemical methods. But these synthesis methods lag because of their various limitations like toxic chemicals (protective agents to maintain stability), which leads to toxicity in the environment, high cost, high pressure and temperature etc.

Keeping these limitations in mind, a novel synthesis technique is introduced i.e. green synthesis or biosynthesis of nanomaterials. This is gaining momentum as green synthesis are nontoxic and environment friendly and safe option, since plant extract-mediated green synthesis of nanoparticles is cost effective and it also gives natural capping agents.

In the green synthesis technique, the biomolecules act as both reducing and/or stabilizing agents to produce biocompatible NPs. These reducing and/or stabilizing agents can be induced by bacteria, fungi, yeasts, algae, or plants as a whole or their products. The solvents and capping agents used have great impact on the physical and morphological characteristics of metal nanoparticles. These variations in the physical and morphological characteristics influenced the applications of the nanoparticles [3, 4, 5].

The present review gives an overview of plant mediated synthesis of metallic nanoparticles by green technology, different parts of plants involved in it; different metallic nanoparticles and its various applications in biomedical fields.

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II. NANOPARTICLE SYNTHESIS METHODS

There are various methods for synthesis of nanoparticles and they are categorised into two approaches i.e bottom-up and top-down method and hence are also applicable for green synthesis of nanoparticles [6].

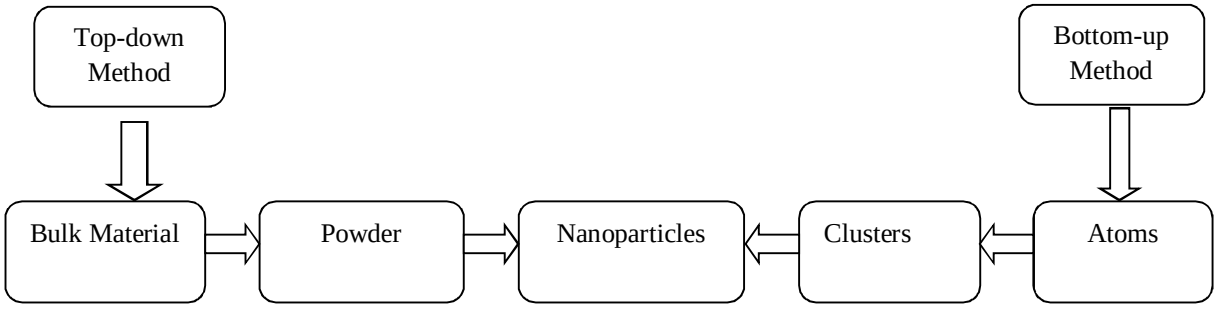

Fig. 1 Synthesis process

A. Bottom-up Method

Bottom-up method for nanoparticles synthesis is the production of nanoparticles from atom to clusters and finally to nanoparticles. Some commonly used bottom-up methods are spinning, chemical vapour deposition (CVD), sol gel, pyrolysis, and green or bio-synthesis for nanoparticle production [6].

B. Top-down method

Top-down method for nanoparticles synthesis is the reduction of a bulk material to nanoparticles and these methods have been used in industries for nanoparticles synthesis. Commonly used top-down approaches are laser ablation, solar flux, sputtering, arc discharge and thermal decomposition [6].

Table I Categories of the nanoparticles synthesised from the various methods [6]

Category	Method	Nanoparticles
Bottom-up	Chemical Vapour Deposition (CVD)	Carbon and metal based
	Sol-gel	Carbon, metal and metal oxide based
	Biosynthesis	Organic polymers and metal based
Top-down	Sputtering	Metal based
	Laser ablation	Carbon based and metal oxide based
	Thermal decomposition	Carbon and metal oxide based

III. EXTENSIVELY USED METALLIC NANOPARTICLES IN PLANT MEDIATED GREEN SYNTHESIS

There are various metallic nanoparticles such as zinc, gold, silver, copper, platinum etc which have been synthesised from plant extracts and have been studied in recent years with various applications. [10].

A. Gold Nanoparticle (Au NPs)

Nanoparticles have potential to fight against cancer cells and this has been a field of interest for researchers. Noble metals like gold (Au), platinum (Pt), silver (Ag) constituent important class of metal nanoparticles. Au NPs have received much attention because of their good biocompatibilty and optical characteristics. Gold NPs have immense applications in various fields, such as catalysts for numerous environmental developments, antimicrobial agents against a wide range of microorganisms, and so on [26-28].

B. Silver Nanoparticle (Ag NPs)

Ag NPs have high electrical and thermal conductivity, high catalytic activity, chemical stability and antimicrobial activities. Because of their anti-microbial and anti-inflammatory properties, it gained much attention as compared to other noble metals [29-31].

C. Cerium oxide (CeO_2) Nanoparticle

CeO_2 is a semiconductor metal oxide with 3.19 eV band gap energy. And have immense applications such as catalyst, sun screen cosmetics, fuel cells, antibacterial activity and as a therapeutic agent against neural diseases [32].

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D. Zinc Oxide Nanoparticles (ZnO NPs)

ZnO NPs have gained research interest in recent years because of their significant and important roles as fuel cells, catalysts, photovoltaic systems, semicondutors, gas sensors, as well as their roles in biological fields and in the energy sector. ZnO NPs have been used in drug delivery in cancer therapy and they posses antibacterial properties [33].

E. Copper oxide Nanoparticles (CuO NPs)

For centuries, CuO has been using for various purposes such as in water purifiers, as antibacterial agent, fungicides etc. Now today also green synthesis of CuO has gained much attention bacause of their many merits like it is highly conductive and also economical as compared to gold and silver. These have vast applications in many fields such as in gas sensors, superconductors, batteries, as an antimicrobial agent etc [34].

IV. DIFFERENT PARTS OF PLANTS USED TO SYNTHESIS METALLIC NPS

There are many chemical methods for the synthesis of MNPs but due to their limitaions of being toxic to environment and also to the human body, green synthesis of MNPs has been introduced which is a novel technique for synthesis of nanoparticles. The biomolecules by green synthesis act as both reducing and stabilizing agents for the nanoparticles. Plant mediated nanomaterial has drawn more attention of researchers due to their unique physicochemical characteristics including optical properties, catalytic activity, magnetic properties, electronic properties, antibacterial properties and hence have extensive application in various fields. The different parts of plant such as leaves, flower, stem, fruit, root, callus, peel and seed are used for metallic nanoparticles synthesis which gives various shapes and sizes [7, 8, 9, 10].

A. Leaves Mediated Synthesis NPs

In the plant derived synthesis of nanoparticles, leaves extract of plant has been used such as Murraya koenigii, P. nigrum, Alternanthera sessilis, Centella asiatica, and many other plants leaves extract have been studied and also found to possess an important bioactive compound which is ecofriendly. P. nigrum leaves extracts act as a capping agent for silver nanoparticles by greebn technique and it also improve the cytotoxic effects of the tumour cells. Plant extract of Artemisia nilagirica shows antimicrobial effect with silver nanoparticles. Also, silver nanoparticles synthesized with the plant extract control different pathogenic condition in human [9] .

B. NPs synthesis from flower extract

Clitoria ternatea, Mirabilis jalapa and Catharanthus roseus flowers extract are used for green synthesis of metallic nanoparticles. The flower extract of Mirabilis jalapa with gold nanoparticles shows reducing agent effect. Extract of rose petals contain sugars and proteins in them and is synthesised with gold nanoparticles by green approach [9].

C. Seeds As A Source For Nps Production

Macrotyloma uniflorum, Phoenix dactylifera, Fenugreek seed extract has been used for synthesis of nanoparticles by green technique. The Macrotyloma uniflorum seed extract contains caffeic acid and showes enhanced reduction rate of silver ions. Phoenix dactylifera seed extract shows prevention option for deadly MRSA which causes infections [11].

D. Stem As Source For Nanoparticle Synthesis

Euphorbia Confinalis, Berberies aristata, Shorea tumbuggaia and many other stems have been used with different metallic nanoparticles by green approach. Plant extract of stem shows functional groups like carboxyl, amine and phenolic compounds that reduces silver ions. Stem extract of Berberis aristata with silver nanoparticles shows antimicrobial activity against Gram-negative bacteria and hence has potential to act as an antimicrobial agent [10,12].

E. Fruits Mediated Synthesis Of Metallic Nanoparticles

Fruits extract of Cleome viscosa, carambola, Malus domestica, Averrhoa bilimbi Linn etc have been studied and also found their antimicrobial, anticancer and antibacterial activities. The fruit extract possess active phytochemical compounds that are liable for the single step reduction reaction. Green synthesis of silver nanoparticles with Cleome viscosa fruit extract showed antibacterial and anticancer activity [10, 13].

Table II
The synthesis of MNPs using different plant extracts.

Plants	Parts of plant	NPs	Size (nm)	Morphology	Reference
Eichhornia crassipes	leaf	ZnO	32	Spherical	[14]
Magnolia kobus	leaf	Cu	37	Spherical	[15]
Magnolia Kobus	leaf	Au	100-300	Hexagonal	[16]
Kalopanax pictus	leaf	MnO_2	19.2	Spherical	[17]
Diopyros kaki	leaf	Pt	2-12	Spherical – plates	[18]
Kalopanax septemlobus	leaf	Ag	30.8	Spherical	[19]
Green Tea	leaf	CaO	86-117	Cubic	[20]
Papaya	leaf	CaO	89-148	Cubic	[20]
Cocous nucifera	flower	Ag	22	Spherical	[21]
Elettaria cardamomum	seed	Au	15.2	Spherical	[22]
Ananas comosus	fruit	Ag	5-30	Spherical	[23]
Vitis vinifera	fruit	Se	3-18	Spherical	[24]
Ficus carica	fruit	Ag	54-89	Spherical	[25]

V. BIOMEDICAL APPLICATIONS OF METALLIC NANOPARTICLES

Green synthesis of plant mediated nanoparticles has many biomedical applications.

A. Plant Derived Metallic Nanoparticles As An Anti-Bacterial Agent

Metals that have been used in the field of nanotechnolgy for synthesis of nanoparticles especially by green technique as an anti-bacterial agent are gold, silver, copper etc. Many reports stated that AgNPs exhibits antibacterial activities against several bacteria [8].

B. Anti-Cancer Activities Of Metallic Nanoparticles

Cancer is a growth of cells which divides in an uncontrolled way. Recently, many studies have stated that plant mediated metallic nanoparticles have potential to control this cancer cell growth to spread without interfering the normal cells by target delivery. Medicinal plant contains bioactive secondary metabolites such as flavonoids, alkaloids, phenols which enhance cytotoxic effect. The plant mediated metallic nanoparticles have potential to possess vast applications in medical field to diagnose and treat various types of cancer [35].

C. Anti-Fungicidal Effects Of Metallic Nanoparticles

Nowadays fungal infection is more prevalent specially in patients who has undergone cancer treatment. Metallic nanoparticles synthesized by green approach has more potential to act as an anti fungal agent than the commercially available antibiotics. In recent study ih has been found that the Ag nanoparticles prevents the growth of dermatophytes, which is responsible for fungal infections. The fungal cell wall is made up of fatty acid and protein. The plant mediated AgNPs have potential to inhibit fungal growth and can also act against spore producing fungus [8,36].

VI. CONCLUSION

Synthesis of metallic nanoparticles by green chemistry approach is very simple, convenient, less expensive, easily scaled up, eco friendly and less hazardous to human body.It also reduces the usage of unsafe and toxic capping/reducing/stablizing agent as in this plant extract has been used in place of capping agent and hence maximizes the efficiency of the whole process. The plant extract-based synthesis of NPs can provide not only more stable in terms of size and shape, also the efficiency of this method is higher than the other conventional methods of nanoparticles synthesis. The plant mediated metallic nanoparticles have immense applications in many fields such as biomedical, agriculture, therapeutics, various industrial and other commercial applications. They have great impact on diagnosis and treatment of various diseases with less and controlled side effects like in the treatment of cancer cells. In future, plants mediated synthesis of MNPs has wide perspective especially in healthcare and commercial products.

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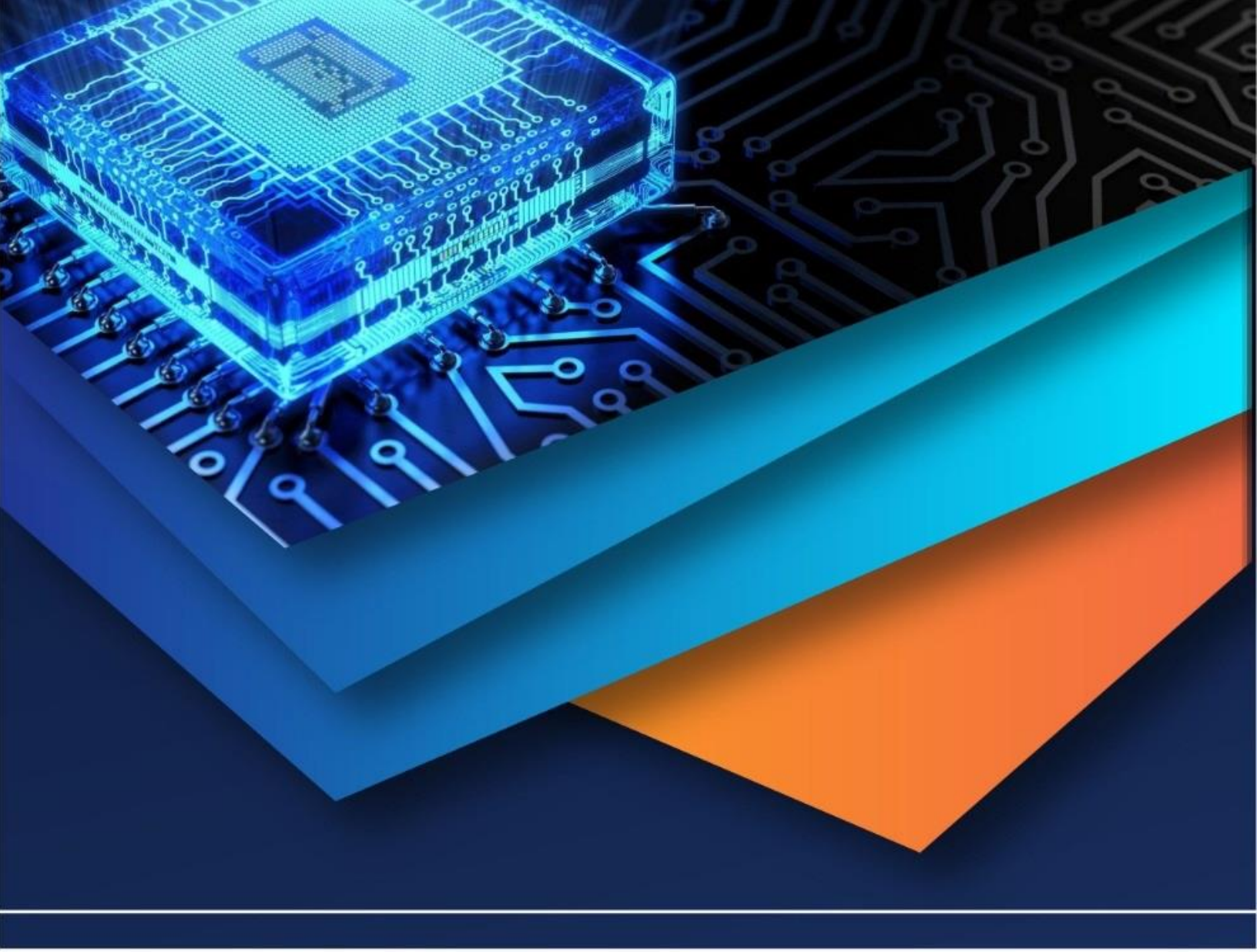

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