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The Green synthesis of silver nano-particle by plant extract

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ABSTRACT: -
Today, the green synthesis of metal nanoparticles is a promising strategy in material science and nanotechnology. In spite of a wide range of biomolecules assisting in the process, synthesizing stable and widely applicable AgNPs by many researchers still poses a considerable challenge to the researchers. other potential bioactivities. The mechanisms of antimicrobial properties of silver nanoparticles are also assessed. Various bioactivity studies connected with green synthesized AgNPs comprising of antimicrobial, antifungal, biocompatibility, anti-inflammatory, anticancer, antioxidant, larvicidal, effect on Seed germination and growth is briefly outlined in this article.

I. INTRODUCTION

Nanoparticles can be described as the groups of atoms in the size range of 1-100nm. The nanoparticles illustrate unique physical, chemical and biological properties owing to their high surface-to-volume ratio [1].

Different types of nanomaterials like copper, zinc, titanium, magnesium, gold, alginate & silver have come up, but silver nanoparticles have proved to be most effective against bacteria, viruses & other eukaryotic microorganisms. Biologically synthesized silver nanoparticles (SNPs) are being widely used. Nanoparticles have been widely used for disinfection of water and to remove arsenic from water. Ag nanomaterials also have many other applications in various fields, such as nanoscale detection and solar cells [2].

It is essential that these NPs be precisely and thoroughly characterized in order to ensure reproducibility in their production, biological activity, and safety. For this purpose, a wide range of physicochemical methods are used to very precisely characterized the synthesized NPs including ultraviolet-visible spectroscopy, Fourier transform infrared spectroscopy (FTIR), attenuated total reflection (ATR), Raman spectroscopy, photoluminescence analysis (PL), dynamic light scattering (DLS), UV-visible diffuse reflectance spectroscopy(UV-DRS), transmission electron microscopy (TEM), scanning electron microscopy (SEM),atomic force microscopy (AFM), field emission scanning electron microscopy (FE-SEM),X-ray diffractometer (XRD), X-ray photoelectron microscopy (XPS), energy dispersion analysis of X-ray (EDAX), thermal gravimetric differential thermal analysis (TG-DTA), or nuclear magnetic resonance (NMR) [6].

Biosynthesis of silver nanoparticles using plant extracts may be influenced directly or indirectly by photochemical in extracts such as phenols, flavonoids and antioxidants as well as the physicochemical factors governing the kinetics of the reactions.This route is preferably docile as it is ecofriendly, involves less energy intensive processes and is cost effective. Moreover, it is an efficient way of waste biomass utilization for the biosynthesis of silver nanoparticles. Currently silver nanoparticles are prepared by different methods including electrolysis, physical, chemical and biological methods [7].

History

About 5000 years ago, many Greeks, Romans, Persians and Egyptians used silver in one form or other to store food products. Use of silver ware during ancient period by various dynasties was common across the globe utensils for drinking and eating and storing various drinkable and eatable items probably due to the knowledge of antimicrobial action. There are records regarding therapeutic application of silver in literature as earlier as 300 BC. In the Hindu religion, till date silver utensils are preferred for the “panchamrit”

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preparation using curd, Ocimum sanctum and other ingredients. The therapeutic potentials of various metals are mentioned in ancient Indian Aurvedic medicine book medicinal literature named “Charak Samhita”. Until the discovery of antibiotics by Alexzander Flemming, silver was commonly used as antimicrobial agent [3] [4].
Scientist Norio Taniguchi, of Tokyo College of Science, describes “nanotechnology in the design, synthesis and reversal of problems with the amount of one atom or one element” for the term “nanotechnology”. In his discussion, he presented the reasons for the use of corn or sedatives. Nanotechnology is a logical breakthrough in the 21st century, with a focus on the subatomic and subatomic levels as well as expanding to a larger scale. Nanotechnology, unique developments to date have provided new facilities and amenities in new areas of research, particularly science and design, such as Raman media (SERS), nanobiotechnology, quantum deserts, and sustainable microbial science [5].

Mechanism of green synthesis of nano particles

The utilization of plant extracts is favourable, as the collection and storage of the plant parts like stem, bark, and leaves are easy and also does not produce any harm to the tree itself too. The utilization of other eco-friendly systems like bacteria and fungi are not preferred much as it necessitates aspatic conditions that are difficult to maintain and expensive isolation techniques. The plant or plant extract-based synthesis of nanoparticles are found to be more beneficial as they lean to be safer, need lesser production time and have a lower manufacturing cost when evaluated to other biological methods. Moreover, the plant-based biosynthesis is a comparatively straight forward procedure that can be smoothly stepped up for large scale generation of nanoparticles. Hence, the plant-based biogenic synthetic protocols are almost hazard-free, financially viable, and environmentally safe. India has a rich diversity in medicinal plants, conventionally the medicinal plant materials have been applied to heal multiple diseases in India. Most of the usually used medicinal plants in India are cheap as they are nontoxic and conveniently available.

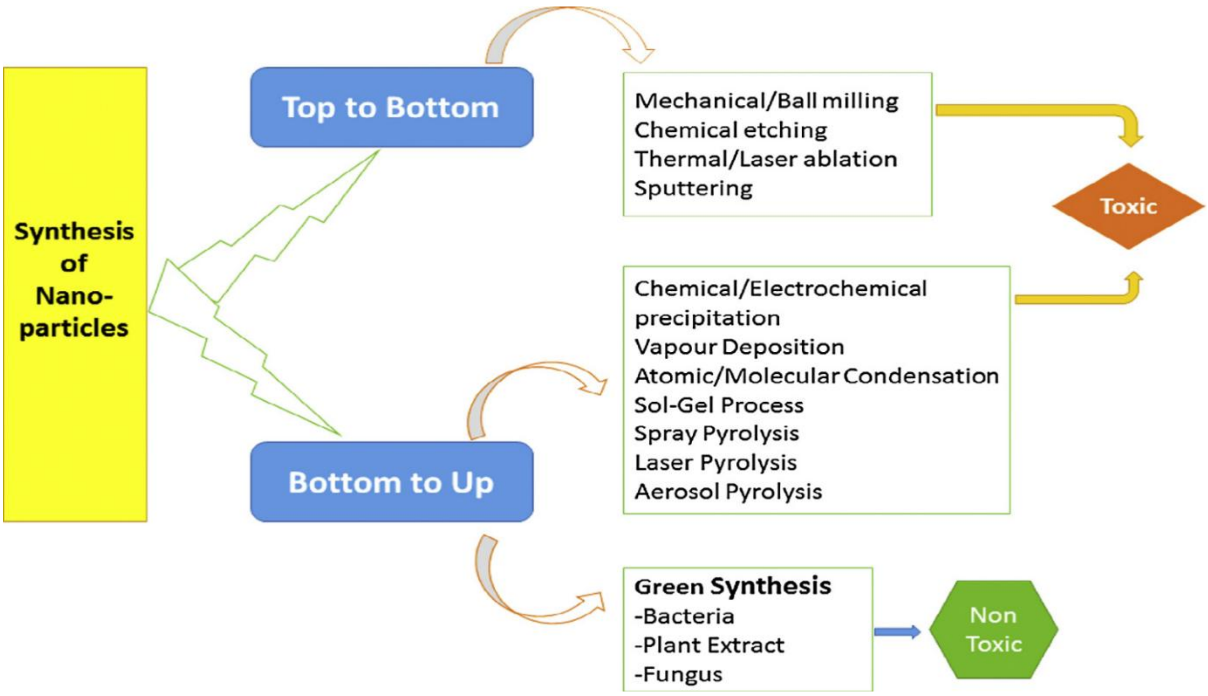

Figure: - Classification of synthesis of nanoparticles

Bottom to top :

In bottom to top approach, chemical reduction is the most common scheme for syntheses of silver nanoparticles. Different organic and inorganic reducing agents, such as sodium borohydride ($NaBH_4$), sodium citrate, ascorbate, elemental hydrogen, Tollen's reagent, N,N-dimethyl formamide (DMF) and poly (ethylene glycol) block copolymers are used for reduction of silver ions (Ag+) in aqueous or non-aqueous solutions. Capping agents are also used for size stabilization of the nanoparticles. One of the biggest advantages of this method is that a large quantity of nanoparticles can be synthesized in a short span of time. During this type of syntheses; chemicals used are toxic and led to non-ecofriendly by-products. This may be the reason which leads to the biosyntheses of nanoparticles via green route that does not employ toxic chemicals and hence proving to become a growing wanton want to develop environment friendly processes. Thus, the advancement of green syntheses of nanoparticles is progressing as a key branch of nanotechnology; where the use of biological entities like microorganisms, plant extract or plant biomass for the production of nanoparticles could be an alternative to chemical and physical methods in an ecofriendly manner [45], [46], [47], [48], [49], [50].

Chemical vapor deposition :

CVD is a diverse and effective approach for generating nanostructures. In the industry of microelectronics, CVD was a major approach for decades and is still one of the most appealing techniques today capable of addressing obstacles that recent technologies imply. NMs are produced with this procedure using very simple materials. A thin coating of gaseous reactants is placed on a substrate utilizing this approach. In a reaction chamber, when gas comes into touch with a heated sub Strate, a chemical reaction happens. As a result, a thin layer is formed on the substrate surface. This thin film is etched out and put to good use [56], [57]. Operating requirements are controlled delivery of gas- phase reactants, availability of an enclosed reaction chamber, discharge of gases, regulation of reaction pressure, delivery of energy source for chemical reactions, clean-up of exhaust gases to attain safe and nontoxic levels, and automation procedure control to increase deposition process's stability [58].

Mechanism. Reactant gases are first delivered toward the reactor. These reactant gases just either proceed through homogeneous reactions in the gas phase to formulate intermediate reactants and by- products of gases, or they diffuse directly on the substrate via bound Ary layer in both conditions, intermediate reactants and reactant gases adsorb and diffuse onto the heated substrate surface. Evaporation of growing species for transport to a substrate where they assemble and grow through a carrier gas. Consequent heterogeneous reactions at the gas-solid interface led to continued thin-film production, as well as production of reaction by products, via coalescence, growth, and nucleation. Eventually, unwanted gaseous products and undissolved species desorb from the reaction zone's surface and are removed. Whenever the temperature is adequately enough or more energy is supplied, such as in form of plasma, gas-phase processes occur. Furthermore, if deposition reaction is dependent on substrate surface catalysis, as with specific metal surface catalytic growth, a heterogeneous reaction is required [59] [60].

- Cooling system to room temperature.
- Introducing a constant flow of carrier gas at a particular pressure. Heat up substrates to suitable substrate temperature.
- Heating source to suitable temperature (beginning of growth).
- Chilling source to heating rate (ending of growth).
- Cooling at room temperature.

Hydrothermal method:

Hydrothermal synthesis is described by the reaction of solid material with an aqueous solution in a reaction vessel at high temperature and pressure and leads toward small particles deposition. Hydrothermal is a solution reaction-based approach. The process is referred to as hydro-thermal because water is used as a solvent in this method. The hydro- thermal procedure is performed in a steel pressure vessel also define as an autoclave where processing conditions are controlled by adjusting temperatures and/or pressures. Temperature is increased beyond the boiling temperature of the water achieving vapor saturation [55].

The hydrothermal technique has a great contribution to recent science and technology owing to homogenous precipitation, low cost, friendly environment, easy scaling up, and pure final product. Moreover, the hydrothermal technique can be separated into hydrothermal synthesis, treatment, and crystal growth, treatment of organic wastes, and prepare functional ceramic powder. Crystal growth performed by the hydrothermal method [55].

Co-precipitation method :

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One of the earliest wet chemical processes of NMs synthesis is co- precipitation. This is the most basic and extensively used approach for producing a wide range of NMs. Impurities precipitate along with the product in this process, although, can be easily separated using different methods such as filtration and washing. The coprecipitation approach refers to the use of a precipitation reaction to achieve a consistent composition of two or more cations in a homogeneous solution. Through numerous chemical reactions in solution, this approach has the advantage of directly producing homogenous NMs with small sizes and size distribution. The solution is combined directly or drop-by-drop with another solution containing dissolved precipitation agents, like sodium hydroxide, ammonia, and many more for retaining up essential pH. Hydroxides, chlorides, carbonates, and oxalates are the most widely employed precipitants in this approach. Precipitates are then aged to produce bigger particles, which are then collected via filtration or centrifugation. To remove contaminants and obtain high purity NPs, additional wash with ethanol, distilled water, or other solvents are required. To obtain NMs with desired crystal structures and morphologies, post-treatment such as annealing, sintering, or calcination is used [55].

Sol-gel method :

The very popular bottom-up approach is sol-gel for the synthesis of NMs owing to its simplicity. It is a mixture of two terms sol and gel. Sol is a form of colloidal solution made up of solid particles suspended in a liquid. The gel is a solid macromolecule that dissolves in a liquid.
The method involves steps: hydrolysis, polycondensation, aging, drying, and calcination [55].

Top-down approach

In case of top to bottom approach; nanoparticles are generally synthesized by evaporation–condensation using a tube furnace at atmospheric pressure. In this method the foundation material; within a boat; place centred at the furnace is vaporized into a carrier gas. Ag, Au, PbS and fullerene nanoparticles have previously been produced using the evaporation/condensation technique. The generation of silver nanoparticles using a tube furnace has numerous drawbacks as it occupies a large space and munches a great deal of energy while raising the environmental temperature around the source material, and it also entails a lot of time to succeed thermal stability. In addition; a typical tube furnace requires power using up of more than several kilowatts and a pre-heating time of several tens of minutes to attain a stable operating temperature. One of the biggest limitations in this method is the imperfections in the surface structure of the product and the other physical properties of nanoparticles are highly dependent on the surface structure in reference to surface chemistry [50], [51], [52].

Mechanical milling or ball milling process of top-down techniques :

The simplest and efficient mechanical method of the top-down approach is ball milling, which produces NPs by attrition. It is the pro- cess of transferring kinetic energy from the grinding medium to the material being reduced. A number of NPs and metal alloys are produced using this process. Temperature and pressure synthesized by the interaction between balls, as well as impact between balls and vessel wall, can cause severe phase transformation at high temperature, a predetermined amount of powder material is poured in milling vial and processed by friction and interaction between vial and balls. It is employed in multiple materials to reduce particle size. Ball milling powder samples have a prominent impact on, crystallite size decrease in particles as well as mechanical dislocation, surface modification, and possible development of metastable phases. It is possible to produce a variety of reactions that do not happen at ambient temperature [61], [62].

The milling process is used for many purposes given below [63]

- Compression in particle size.
- Growth of particle size.
- Change in particle structure.
- Agglomeration.

Thermal evaporation :

It's an endothermic method in which heat causes chemical break- down. This heat breaks a chemical link in a molecule. Thermal evaporation is one of the very common procedures for producing stable monodisperse suspensions with self-assembly ability among numerous various approaches for the production of inorganic NPs. Thin films are generated on a variety of substrates utilizing thermal evaporation [64], [65].

Laser ablation :

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The term laser refers to a high-intensity beam of electromagnetic radiation that is amplified through stimulated emission of radiation. Einstein was the first person to propose a laser hypothesis. Synthesis of NPs from diverse solvents utilizing laser ablation synthesis in solution is an uncomplicated process. Since Maiman built the first practical laser in 1960, lasers have been generally employed utilized in fields of information transmission, medical treatment, industry, and military. Laser ablation (LA), which utilizes a pulsed laser to remove molecules from a substrate surface to create [formulate, devise, make] micro/nano structures, has multiple applications in metals, ceramics, glasses, and polymers. LA is a top-down procedure of eliminating the substance from a substrate by concentrating a laser beam above it. Only when a substance absorbs enough energy to melt or evaporate does ablation occur. In laser machining applications including high-precision drilling, laser beam milling, and laser cutting, the overall procedure of laser ablation is constant. Ablation is a term that refers to a procedure that involves both vaporization and melts ejection [66], [64], [67].

Sputtering :

Sputtering is more significant among bottom-up approaches owing its non-thermal vaporization process. The. Sputtering procedure can be achieved at <0.67 Pa, low pressure will maintain by utilizing a vacuum pump. Different parts of the sputtering system include:

1) Evacuated chamber
2) Sputtering source
3) Gas supply
4)Electrode
5)Substrate

In this process of sputtering, nanomaterials are deposited on a substrate's surface by ejecting particles with the attack of high energy ions. The sputtering procedure is used for surface coating, thin layer deposition, and surface etching application. Glow discharge sources are working by using an electric potential between the electrode in a gas phase in a low-pressure environment. As electrons accelerated and collide with a gas atom, such ionized gas is called plasma. These plasma ions are the simplest source for sputtering [68], [69], [70], [71], [72].

General protocol for the synthesis of nanoparticles

In order to obtain AgNPs from the above-mentioned plants, two kinds of extracts can be used: aqueous or alcoholic and, in the most of cases, aqueous plant extracts are chosen because of the further utilization of the synthesized AgNPs in medical or biological applications.

The steps involved for obtaining aqueous plant extract are:

- collecting the plant's parts that are of interest;
- washing thoroughly with tap and distilled water;
- shade-drying 7-10 days (or more if necessary);
- grinding the dried part of the plant to a fine powder;
- boiling a determined quantity of the dried powder with distilled water;
- filtering the resulted infusion until no debris is present.

Once the aqueous plant extract is obtained, few ml is added to an $AgNO_3$ solution in order to reduce pure Ag (I) ions to Ag (0). The formation of AgNPs can be conveniently observed by monitoring the colour changes to brown and by recording the UV-Vis spectra at different time intervals.

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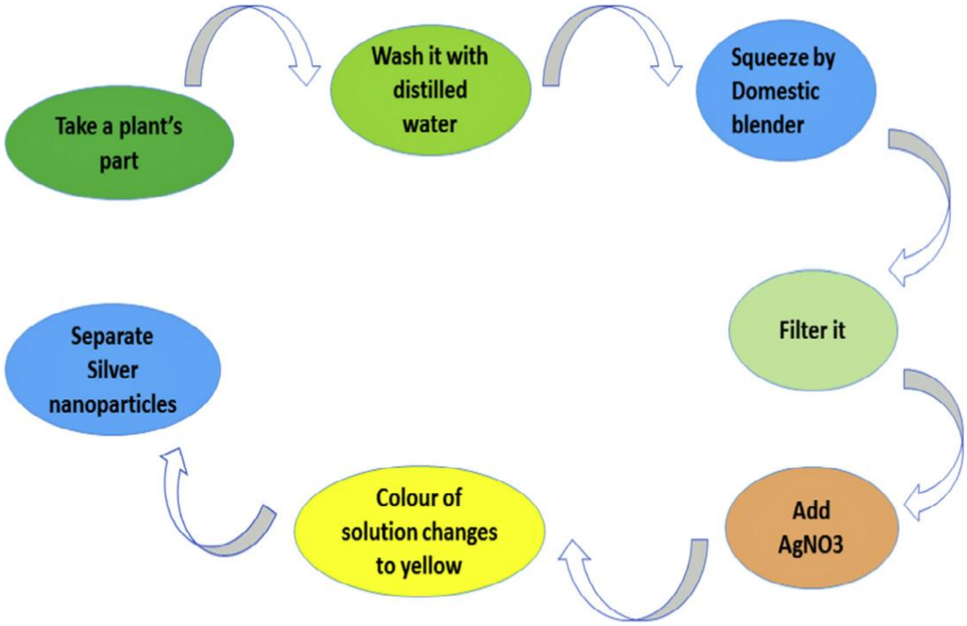

Fig. General protocol for synthesis of nanoparticles

Plants used for green synthesis of nano particles

Sr.no.	Plant	Size (nm)	Plant part	Reference
1.	Ficus carica	13	leaves	Geetha N et al. (2014)
2.	Moringa oleifera	57	leaves	Prasad and Elumalai. (2011)
3.	Acalypha indica	20-30	leaves	Krishnaraj et al. (2010)
4.	Carica papaya	25-50	leaves	Jain D et al. (2009)
5.	Datura metel	16-40	leaves	Kesharwani J et al. (2009)
6.	Aloe vera	50-350	leaves	Chandran SP et al. (2006)
7.	Tea	20-90	leaves	Nabikhan A et al. (2010)
8.	Eucalyptus hybrid	50-150	peel	Dubey M et al. (2009)
9.	Acorus calamus	31.83	rhizomes	Nakkala JR et al. (2014)
10.	Saraca indica	20	leaves	Perugu S et al. (2015)
11.	Azadirachta indica	20	leaves	Banerjee P et al. (2014)
12.	Cucurbita maxima	19	petals	Nayak D et al. (2015)
13.	Emblica officinalis	25.4	leaves	Latha M et al. (2015)
14.	Annona muricata	20.53	leaves	Santhosh SB et al. (2015)

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15.	Citrus limon	10-30	peel	Mohapatra et al. (2015)
16.	Ocimum sanctum	4-30	leaves	Singhal et al. (2011)
17.	Allium cepa	33.6	leaves	Saxena et al. (2010)
18.	Bryophyllum	18-21	leaves	Saikia et al. (2015)
19.	Capsicum annum	30-70	leaves	Li et al. (2007)
20.	Euphorbia hirta	40-50	leaves	Elumalai et al. (2010)
21.	Lantana camara	12.55	leaves	Sivakumar et a. (2012)
22.	Mentha piperita	90	leaves	Ali et al. (2012)
23.	Citrullus colocynthis	31	leaves	Satyavani et al. (2007)
24.	Centella asiatica	-	leaves	Palaniselvam et al. (2011)
25.	Morinda tinctoria	79-96	-	Vanaja et al. (2014)
26.	Morindapubescens	25-50	leaves	Mary and Inbathamizh (2014)
27.	Morindacitrifolia	30-55	root	Suman et al. (2013)
28.	Aervalanata	18.62	leaves	Joseph et al. (2014)
29.	Zizipus jujube	20-30	leaves	Gavade et al. (2015)
30.	Nelumbo nucifera	16.7	root	Sreekanth et al. (2014)
31.	Prosopis farcta	10.8	leaves	Miri et al. (2015)
32.	Cocos nucifera	22	coir	Roopan et al. (2013)
33.	Lansiumdomesticum	10-30	fruit	Shankar et al. (2014)
34.	Rosmarinus officinalis	10-33	leaves	Ghaedi et al. (2015)
35.	Skimmialaureola	46	leaves	Ahmed et al. (2014)
36.	Tephrosia tinctoria	73	stem	Rajaram et al. (2015)
37.	Quercus branti	6	leaves	Korbekandi et al. (2015)

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APPLICATION OF SILVER NANO PARTICLES

Due to their different properties, AgNPs have been broadly utilized in household utensils, food storage, and health care industry, environmental, and biomedical applications. The present review encompasses a discussion on different biological properties of the AgNPs, emphasizing anti- inflammatory, anticancer, and anti-angiogenic properties and the antimicrobial potential of AgNPs against different classes of microorganism, viz., bacteria, fungi, and viruses.

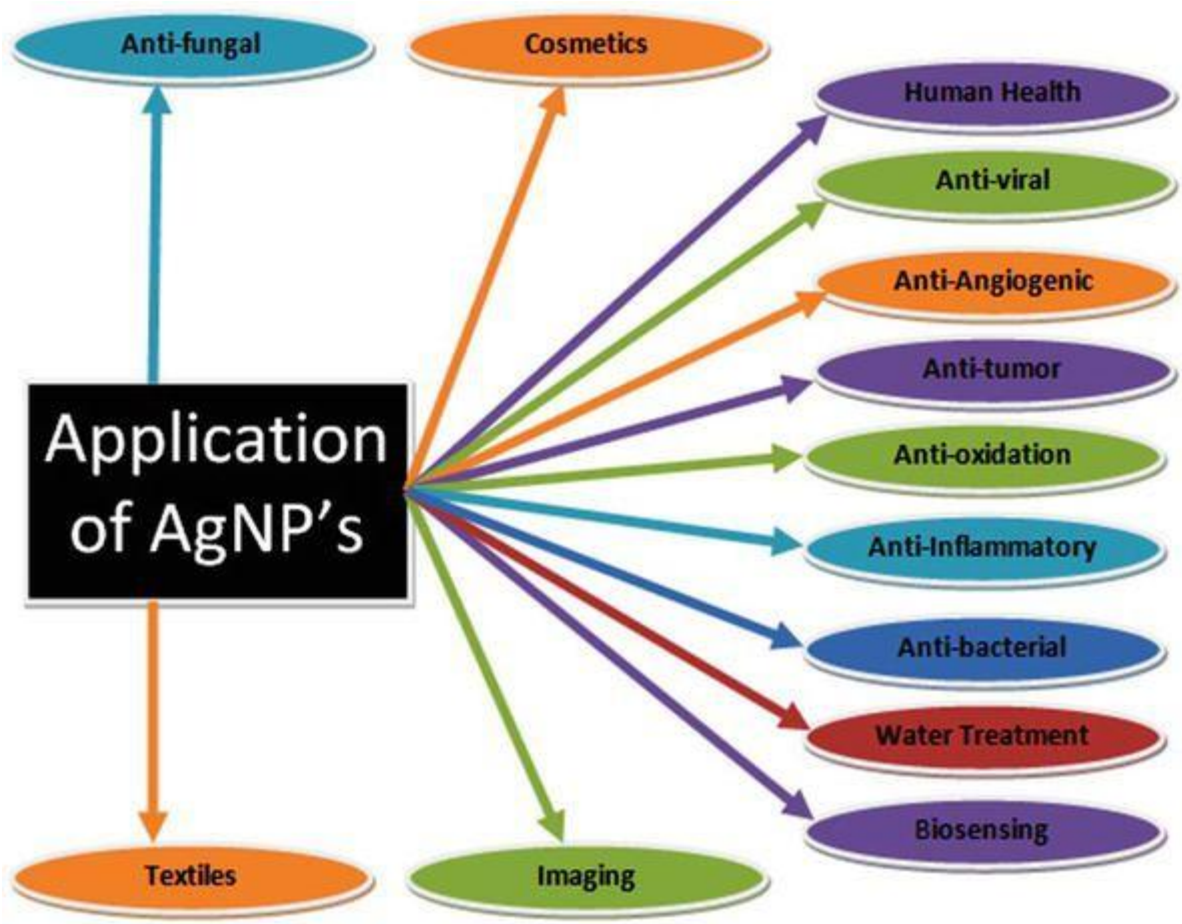

Fig. Application of silver Nanoparticles

Characterization of Nano particles:

It is essential that these NPs be precisely and thoroughly characterized in order to ensure reproducibility in their production, biological activity, and safety. For this purpose, a wide range of physicochemical methods are used to very precisely characterized the synthesized NPs including ultraviolet-visible spectroscopy, Fourier transform infrared spectroscopy (FTIR), attenuated total reflection (ATR), Raman spectroscopy, photoluminescence analysis (PL), dynamic light scattering (DLS), UV-visible diffuse reflectance spectroscopy(UV-DRS), transmission electron microscopy (TEM), scanning electron microscopy (SEM),atomic force microscopy (AFM), field emission scanning electron microscopy (FE-SEM),X-ray diffractometer (XRD), X-ray photoelectron microscopy (XPS), energy dispersion analysis of X-ray (EDAX), thermal gravimetric differential thermal analysis (TG-DTA), or nuclear magnetic resonance (NMR) [6].

The formation of the AgNPs during their green synthesis was monitored by UV–Vi's absorption spectroscopy. The absorbance spectra of the reaction mixtures were acquired by a Shimadzu UV–Visble spectrophotometer, model UV-1800 in the range of 200–800 nm, at dierent time intervals. For the blank sample, the distilled water was considered [5].

The size distribution and the morphological characteristics of the greenly synthesized AgNPs were evaluated by a Philips GM-30 transmission electron microscope (Hillsboro, OR, USA), at an accelerating voltage of 120 kV, with a resolution of 2.5 Å, as suggested by the TEM instrument supplier. For the preparation of the samples, the cleaned AgNPs were re-dispersed in a solution, and one drop of this solution was placed on a copper grid, followed by the evaporation of solvent under an infrared lamp. The Digimizer software (version 4.1.1.0) was applied for the measurement of the particles size distribution, using the TEM images [5].

UV–Visible Spectroscopy:

The UV–visible spectroscopy, which enables us to measure the characteristic localized surface plasmon resonance (LSPR) absorption peak, was used to evidence the green synthesis of the AgNPs. The UV–vis spectra of the resulting reaction mixtures were determined at various time intervals (30, 60, 120, and 240 min) after starting the reaction. The spectra showed that the intensity of the LSPR absorption peak increased with the lapse of time, and its maximum was recorded at nearly 430 nm. This LSPR absorption peak was related to the formation and presence of the nearly spherical AgNPs [5] [54].

Size and morphology:

The particle size is one of the most important parameters of nanoparticles. Particle size and sizing of sub-optical particulates is a different procedure, as it involves not only procedural variability, but some of the surface associated properties may even change during sizing procedure. Two main techniques are being used to determine the particle size distribution of nanoparticles and include photon correlation spectroscopy (PCS) and electron microscopy (EM). The latter includes scanning electron microscopy (SEM), transmission electron microscopy (TEM) and freeze-fracture techniques. The size evaluation of nanoparticle dispersion demonstrates better results with freeze-fracturing microscopy and photon correlation spectroscopy as quantitative methods. The freeze-fracturing with poly (methyl methacrylate) is confronted with and interrupted by in process particles aggregation which only yields a few discrete particles for size measurement or analysis. The electron microscopy, however, could be adopted as an alternative option, which measures individual particles for size and its distribution. It is relatively less time consuming. Additionally, freeze fracturing of particles allows for morphological determination of inner structure of particles. In combination with freeze fracture procedures, TEM permits differentiation among nano capsules, nanoparticles and emulsion droplets. Similarly, scanning electron microscopy is much less time consuming. However, since particles are based on organic and non-conductive material, they require gold coating. The thickness of gold coat may vary from 30-50 nm. Thus, determined size should be denoted as gold-coated particle size rather than as particle size. Mercury porositometry is equally suitable technique for the sizing of nano-particulates. The freeze-dried nanoparticles are filled in a dilatometer under vacuum and then measured with the help of a mercury pressure porosimeter. The method largely measures particulate agglomerates as mercury fails to penetrate to a greater extent within the primary particles [53].

Surface charge and electrophoretic mobility:

The nature and intensity of the surface charge of nanoparticles is very important as it determines their interaction with the biological environment as well as their electrostatic interaction with bioactive compounds. The surface charge of colloidal particles in general and nanoparticles in particular can be determined by measuring the particle velocity in an electric field. Laser light scattering technique, i.e., Laser Doppler Anemometry or Velocimetry, has become available as fast and high-resolution technique for the determination of nanoparticle velocities. The surface charge of colloidal particles could also be measured as electrophoretic mobility. The charge composition critically decides the bio- distribution of drug carrying nanoparticles. Generally, the electrophoretic mobility of nanoparticles is determined in phosphate saline buffer (PBS. pH 7.4) and human serum. The aggregated bands of nanoparticles are visualized distinctively. It is important that free drug adherent or solubilized in aqueous phase and residual surfactant should be removed before electrophoretic mobility is determined. Repeated washing using centrifugation, however, may lead to aggregation. Nevertheless, the aggregated nanoparticles suit best for electrophoretic mobility determination as they contribute to a well visible band [53].

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Surface hydrophobicity:

The surface hydrophobicity of nanoparticles has a particle has an important influence on the interaction of colloidal particles with the biological environment (e.g., protein adsorption and cell adhesion). The hydrophobicity and hydrophilicity collectively determine the bio-fate of nanoparticles and their contents. Hydrophobicity regulates the extent and type of hydrophobic interactions of nanoparticulate with blood components. Several methods, including hydro- phobic interaction chromatography, two-phase partition, adsorption of hydrophobic fluorescent or radiolabelled probes, and contact angle measurements have been adopted to evaluate surface hydrophobicity. The measurement of angle of contact suggests about the hydrophobicity or hydrophilicity of the nanoparticles. The water contact angle is measured only on plain surface hence nanoparticles are compressed as tablet/pellet. To study the effect of blood components on resultant in vivo hydrophilicity or hydrophobicity the particles are first incubated with blood serum, then centrifuged and lyophilized. The dried nanoparticles are then compressed and angle of contact with water (water contact angle) is determined. The serum components decrease the contact angle by 20°. This suggests that blood components are adsorbed strongly and affect subsequent wettability characteristics of the nanoparticles. Recently, several sophisticated methods of surface chemistry analysis have been used. For example, X-ray photoelectron spectroscopy (XPS) permits the identification of specific chemical groups on the surface of nanoparticles [53]

Density:

In addition to surface scanning electron microscopy, transmission electron microscopy following freeze fracturing could successfully be used in morphological investigation of nanoparticles. The interiors are continuous, or some structural imperfections exist that provide an indication about the density distribution across the matrix. Some (% w/w) polymeric nanoparticles specially Poly cyanoacrylate and poly (methyl methacrylate) seem to have porous interior and they also exhibit more irregular and rougher surface. The density of nanoparticles is determined with helium or air using a gas Pycnometer. The value obtained with air and with helium may differ noticeably from each other. The difference is much more pronounced due to specific surface area and porosity of the structure [53].

Molecular Weight Measurements of Nanoparticles:

Molecular weight of the polymer and its distribution in the matrix can be evaluated by gel permeation chromatography using a refractive index detector (van Snick et al., 1985). Sukuma and co-workers, 1997 determined the number average and weight average molecular weight of macromolecules on the polystyrene nanoparticles having surface grafted hydrophilic polymeric chains and correlated these parameters with a good water dispersibility of the system. Using gel permeation chromatography, it was shown that PACA nanoparticles are built by an entanglement of numerous small oligomeric subunits rather than by the rolling up of one or a few long polymer chains [53].

II. CONCLUSION:

The growing need for green chemistry and nanotechnology has pushed for the growth of green synthetic methods approaches for the production of nanomaterials utilizing plants, microbes, and other natural resources. Researchers have been focusing on the green synthesis of NPs, using an environmentally favourable technique. Due to their cost-effectiveness, nontoxic approach, simple availability, and eco-friendly nature, considerable research has been conducted on plant extract-mediated NPs production and their prospective uses in many industries. Synthesis of silver nanoparticles is effectively established using plants belong to Acantharean family. The phytochemicals present in the family members serve as both stabilizing and capping agents of the synthesized nanoparticles.

Metal NPs have a range of uses and are commonly studied in biomedical, agricultural, food, herbal, and several different fields. The 'green' route for synthesising metal NPs has significant potential owing its substantial advantages like eco friendliness, economic perspective, and feasibility over the classical methods. By 2027, the market for metal NPs is anticipated to grow to $40.6 billion. Henceforward, plants have an enormous role in synthesising metallic NPs, specifically in the healthcare sector. These plant-mediated NPs can serve as a promising option to dealing with pathogens and effectively solve the issues arising from mutation and drug resistance. However, toxicity evaluation and scale-up of these NPs are the prime concerns ahead of their use as therapeutic agents.

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