Plant Mediated Nanoparticle Synthesis, Characterization and its Applications in Various Fields: A Review

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Abstract

Nanoparticle synthesis using various parts of plants (Flower, leaf, fruits, and roots) and metal salts has become demanding research area due to its vast application in various fields like medicine, health, electronics, environment, farming, cosmetics and industries. Green approach behind this synthesis as avoiding toxic chemicals, ecofriendly, and cost effectiveness attracted many researchers towards it. Use of natural sources like plant parts and its biological activities enhances the effectiveness of nanoparticles. Such nanoparticles useful in medicinal field due its anticancer, anti-infective, antiviral activities also important in drug delivery, disease diagnosis and biomarkers.

This review focuses on the nanoparticle synthesis using plant parts and metal salts, their characterization and applications in various fields.

Keywords: Nanoparticle, SEM, Photo catalytic activity, green synthesis

1. Introduction

Nanotechnology includes the manipulation of materials at Nano scale ranging from 1 to 100 nm. This involves control of properties at molecular and atomic level. Green synthesis of AuNPs has numerous advantages over chemical and physical methods: profitability of being easily expanded for large scale synthesis without any need for high pressures, energy environment, temperature and toxic chemicals. The synthesis of AuNPs using plant materials is a conventional eco-friendly method when compared to chemical and physical synthesis. Since plants are widely distributed, readily available and at the same time safe to handle there will be a lot to do to develop this method of synthesis inspired by several conventional ideas. [1]. Nanotechnology is playing a critical role in many significant technologies via nanoscale structures (nanoparticles) in areas of optics, electronics, biomedical science, mechanics, drug-gene delivery, chemical industry, optoelectronic devices, nonlinear optical devices, catalysis, space industries, energy science, and photo electrochemical applications. [2] Many researchers and scientists have shown great interest in their unique features and found that, however, these have outstanding applications in various fields, but numerous nanoparticle materials revealed toxicity at the nanoscale size. To overcome the problem of toxicity, nanotechnology and green chemistry merge to fabricate nature-friendly nanoparticles via plants, microbes, etc.[3] Researchers have developed many synthetic routes for nanoparticle fabrication which unveiled a notable benefit to nature & environment via clean, nontoxic, and environmentally adequate green chemistry" methods which include organisms such as bacteria, fungi, plants.[4]

Nanoparticles play a crucial role in nanotechnology due its unique properties such as their surface area to volume ration and quantum effect at Nano scale which make them ideal for various applications. Nanoparticles are of different types 1) metallic nanoparticles involves pure form of metal based nanoparticles 2) metal oxides nanoparticles use metal oxides. 3) Polymeric nanoparticles also known as colloidal solid particle with size ranges from 10-1000 nm containing active ingredient entrapped on surface adsorbed on polymeric core. 4) Carbon based nanoparticles are made of carbon compound. In this review we exploring plant mediated nanoparticle synthesis green approach and its applications in various field.

2. Synthesis of Nanoparticles

- Nanoparticle synthesis can be produced by wide-ranging synthetic routes in which very common routes are physical, chemical, and biosynthetic. Conventional methods either physical or chemical method are too expensive and uses toxic and hazardous chemicals which further responsible for producing toxic side products and various risks to the environment. [5] to overcome this problem alternate greener approach is far better and safe. The biosynthetic method is biocompatible, environment-friendly. Synthesis of nanoparticles by green approach using plants and microorganisms for biomedical applications. [6] Green synthesis can be carried out with fungi, algae, bacteria, and plants. Different parts of the plants such as fruits, leaves, roots, stem, seeds have been used for the synthesis of various nanoparticles as they consist of phytochemicals in its extract which act as reducing agent and stabilization agents [7] Green synthesized nanoparticles produced using environmentally friendly methods involving plant extract crucial for reducing the environmental impact of nanotechnology, promoting sustainability and improving health and safety in manufacturing process. It minimized the use of hazardous chemicals, energy consumption. It has advantage over conventional methods such as environmental impact, cost effectiveness scalability and potential for novel properties in nanoparticles that lacks in conventional methods. Synthesis of nanoparticles is not sufficient for large scale scalability issues, stability concerned and emerging trends has to be counted to drive innovation in this field along with novel applications. Efficiency of plant extracts over microbes is more with respect to the production rate. They reduce metal-ions faster than microbial entities and produce nano-sized materials, which are also very stable. [8, 9] Plants contain various phytochemicals like carbohydrates, alkaloids, polyols, flavonoids, terpenoids, phenol, tannin, alcohol with the competence to reduce metallic ions to nanoparticles with desired stability.[10, 11]
- Synthesis of nanoparticles mainly based on two approaches Top-down approach uses initial macroscopic structures. The methods starts with larger particles which are reduced to nanoparticles after a sequence of operations performed over them. This methods are rather expensive and not suitable for bulk production. The method can be apply in laboratory experimentation. The approach is based upon the grinding of materials. These methods are not suitable for soft samples. [12, 13] In Bottom-up approaches smaller entities used for producing nanoparticles. Initially nanostructured building block are formed which assemble together to produce nanoparticles. Self-assembly principle used here means growing more and more things about one's kind from themselves. Many of these techniques are still under development or are just beginning to be used for the commercial production of nanoparticles. [14, 15].
- Green synthesis of nanoparticles consist of three stages activation, growth and termination. Activation phase involves reduction of metal ions and nucleation of reduced metal atom. Growth phase involves

coalesce of small adjacent nanoparticles to larger size. Termination phase determines the final shape of nanoparticles. [38]

3. Characterization

Different techniques used for the characterization as follows

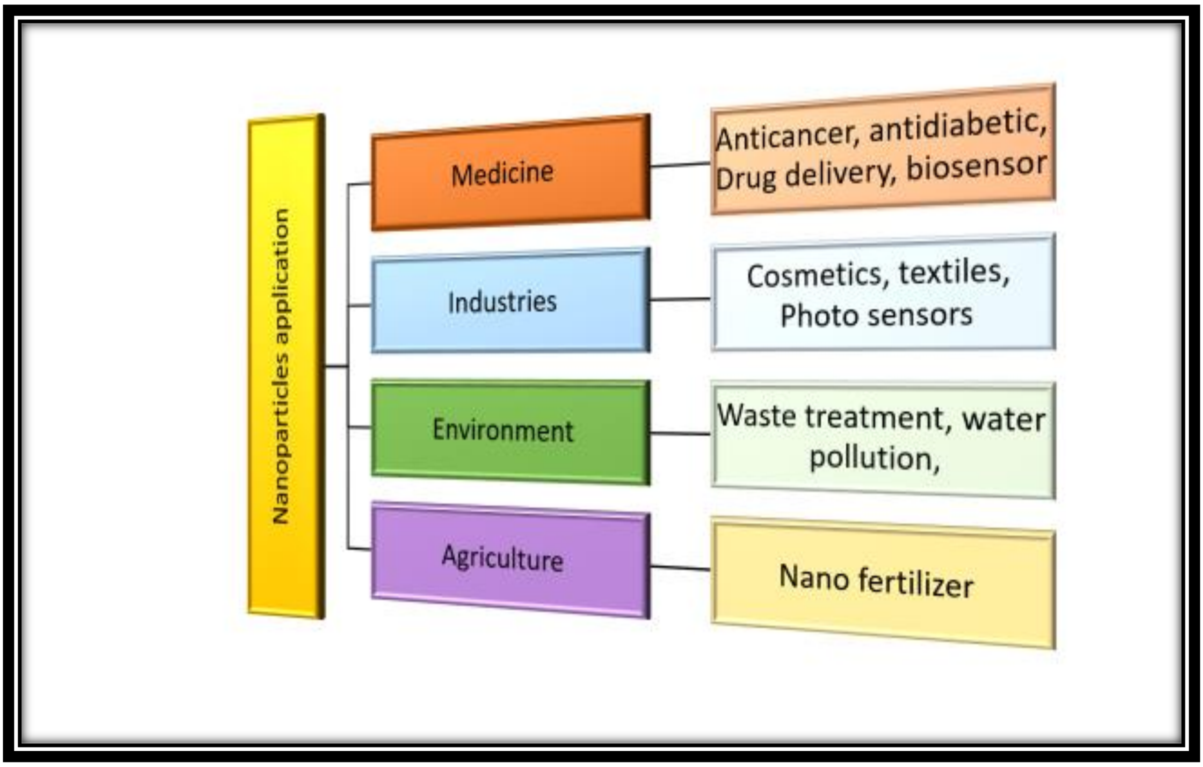
- **UV Visible spectroscopy:** This spectroscopic analysis technique used to quantify light which is absorbed and scattered by a sample
- **Transmission Electron Microscopy (TEM) :** In this technique high magnification measurement of that images transmission of beam of electrons through a sample. It has higher resolution than light based imaging techniques. Tem directly measures the particle size, distribution and morphology of nanoparticles.
- **Scanning Electron Microscopy(SEM) :** It measures the electron scattered from the sample, used for determination of size shape and morphology of nanoparticles in the form of images of surface of the sample.
- **Dynamic light scattering(DLS) :** This techniques measures the scattered light obtained from colloidal solution when laser passes through it. The analysis is based on diffusion of particles on solution
- **X-ray Diffraction (XRD):** X-ray Diffraction is a powerful technique for analyzing the crystalline structure of nanoparticles. By directing an X-ray beam onto the sample, the resulting diffraction pattern reveals information about the lattice spacing and crystal orientation. XRD can be employed to determine the composition, phase purity, and crystallinity of nanoparticles, aiding in material identification and characterization.
- **Surface Enhanced Raman Spectroscopy (SERS):** Surface Enhanced Raman Spectroscopy allows amplification (~108 or greater) of Raman signals by the electromagnetic field generated by the excitation of localized Plasmon resonance broadly used in nanomaterial characterization
- **Fourier Transform Infrared Spectroscopy (FTIR):** Fourier Transform Infrared Spectroscopy enables the identification of functional groups and chemical bonds in nanoparticles. By measuring the absorption and transmission of infrared light, FTIR provides information about the composition, surface chemistry, and molecular interactions of nanoparticles. This technique helps in understanding surface modifications and coatings on nanoparticles.

4. Applications of Nanoparticles in various field

Plant mediated synthesised nanoparticles has wide range of application in different fields like medicine, industries, environment, and agriculture. Zinc, manganese, and iron nanooxides have been successfully synthesized via a green chemistry technique using a microwave-assisted hydrothermal method. The resulted nanooxides have an average particle size around 20-60 nm and small surface areas. These oxides were applied as a foliar nanofertilizer on squash plants. The use of the prepared nanooxides as a foliar application improved the growth and the yield in comparison with untreated plants [16] Jain Devendra and Kothari SL. [17] reported green synthesis of silver nanoparticles having average particle size of 15nm.This finding suggests that silver nanoparticles are effective antiviral agent. Metallic nanoparticles have been effectively used against many species of parasitic larva and adult's insects. Benelli et al. [18] explore biomedical potential of green mediated TiO_2 NPs. Rajakumar and colleagues [19] reported the main stream application includes photodynamic cancer treatment, antileshmanial agent and antimicrobial therapies. [20, 21].

Zengsheng Han et al [22] reported green synthesis of Pd NP. Palladium -lentinans nanoparticles had a small size 2.35–3.32 nm , were stable in solution for 7 days and has higher catalytic activity towards the reduction of 4-nitrophenol than other catalysts. Eco-friendly green synthesis of copper nanoparticles (CuNPs) using Celastrus paniculatus leaves extract was reported by S.C. Mali et al. [23] with size ranged between 2-10 nm with an average particle diameter of 5 nm. CuNPs possessing antifungal activity fungi Fusarium oxysporum. Narayanaswamy Krithiga et al. [24] synthesized silver nanoparticles using *Clitoria ternatea* and *Solanum nigrum* leaves extract had bactericidal activity and can be used in wound healing, water purification and medicine Also Green synthesized AgNPs using C. prophetarum possessing

Figure 1: Application of plant mediated nanoparticles in various fields



antibacterial and antiproliferative effects on different human cancer cell lines[25] Green synthesis of Gold Nano particles using M. oleifera plant leaves extract reported [26] antibacterial, antimicrobial and photo catalytic activity.

Alaa A. A. Aljabali et.al [27] reported no antimicrobial or antifungal activity of AuNPs up to concentrations of 5 mg/mL, which opens the possibility for the use of AuNPs for drug delivery, oral or intranasal, without interfering with the human microbiota. Behera A et al. [39] reported the green synthesis of Selenium Nanoparticles from Clove possessing antioxidant, antibacterial properties. Also antiangiogenic actions and biocompatibility.

Eco-friendly synthesis of silver-iron oxide bimetallic nanoparticles using cabbage peel extract exploited by Dahir Sagir Idris, Arpita Roy [40] showing antioxidant and catalytic applications, especially in addressing dye-contaminated wastewater treatment. Nehru, L et al [41] conveyed antimicrobial, antioxidant, anti-inflammatory, and antidiabetic properties of green synthesize ZnONPs using the biomass filtrate of endophytic *Xylaria arbuscula* . Fig. 1 shows the chart of different application in this above mention fields.

Table 1: List of different nanoparticles and their application

Nanoparticle	Size in nm	Application	References
Gold Nanoparticle	13 ± 41	Anticancer activity	[28]
Silver Nanoparticle	5–10	Antioxidant	[29]
Copper Nanoparticle	15–22	Antibacterial, antioxidant, and anticancer	[30]
Palladium Nanoparticle	9-44	Antioxidant	[22]
Zinc oxide Nanoparticle	50 20–22	Antimicrobial Antidiabetic	[31] [32]
Titanium oxide Nanoparticle	10	Photo catalytic activity	[33]
Platinum Nanoparticle	1–6	Antimicrobial and anticancer agent Antibacterial	[34]
Selenium Nanoparticle	113 4–16	Antitumor activity Chemotherapic agent for human liver cancer Antimicrobial activity	[35] [36]
Iron Nanoparticle	2–10	Cancer hyperthermia, drug delivery	[37]

5. Conclusion and Future scope:

Green synthesis of nanoparticles has many advantages like eco-friendly production, cost effectiveness, sustainability, and energy efficient, producing less toxic waste over chemical methods. Green synthesis contributes to a more sustainable and responsible approach to nanoparticle synthesis by embracing eco-friendly practices and reducing environmental footprints. Plant mediated nanoparticle synthesis has to face some challenges while processing on large scale such as scalability issues, stability concerned. Exploring new application materials and technology to drive innovation and competiveness in the field of plant mediated (green) nanoparticle synthesis research and development.

This review tries to explore the key discoveries and advancement in green synthesis of nanoparticles highlighting the significant environmental sustainability, economic efficiency and technological innovation. Future research areas like nano toxicology, nanobiology, nanocomposites and green catalysis for continual progress and innovation in this field. Encouraging collaborations between academia, industry and government agencies to foster knowledge exchange promoting synergistic efforts for sustainable development in green synthesis

6. References

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