**GREEN SYNTHESIS OF NANOPARTICLES**

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**Abstract**

As the globe becomes greener, eco-friendly practices that protect the environment for to come generations are promoted. As a result, the world values the long-lasting qualities of personalized nanomaterials more than the diverse uses of nanotechnology, particularly in the medical industry. As a result, the capacity of nanotechnology to "go green" will determine its destiny. Green nanotechnology uses environmentally friendly components to create better, non-hazardous and environmentally friendly nanomaterials with long-term advantages. Though green nanotechnology is regarded as a feasible, sustainable, and biocompatible method of producing environmentally benign nanomaterials, it has limitations, particularly in germ management and process optimization techniques. This chapter deals with the concept of green synthesis and major advantages and applications.

**Keywords:** Nanotechnology, Top-Down Approach, Bottom- Up Approach, Green Synthesis

**Introduction**

Due of the numerous applications of nanoscale metals in fields including engineering, medicine, and the environment, their synthesis is an important and contemporary problem. Currently, the majority of nanoscale metals are produced chemically, which has unforeseen consequences such as increased energy consumption, environmental pollution, and possible health issues [1]. The top-down and bottom-up approaches are most frequently used to synthesis nanoparticles. Top-down operations are manual processes that include shaping, cutting, and grinding materials with tools. Conversely, bottom-up strategies are believed to be the most efficient for producing nanoparticles. These strategies involve the use of chemicals or biological processes to allow atoms or molecules to self-assemble into larger particles. In response to these problems, green synthesis was created, which lowers metal ions by using plant extracts rather than synthetic chemical agents. The green synthesis of metallic nanoparticles has become a hot research topic in recent years. Because it is quick, affordable, produces nanoparticles with good stability, requires less time, produces non-toxic byproducts, and is environmentally benign, green synthesis of nanoparticles has been increasingly popular in recent years. It can also be easily scaled up for large-scale synthesis [2]. Many different microorganisms, including bacteria, fungus, and yeast, as well as plants, have been used to produce metal nanoparticles. In order to avoid the production of unwanted or dangerous by-products, "green synthesis" is necessary. This is done by creating dependable, long-lasting, and environmentally friendly synthesis processes. Utilizing the proper solvent systems and natural resources (such as organic systems) is crucial for achieving this goal. Different biological elements, such as bacteria, fungi, algae, and plant extracts, have been incorporated using green metallic nanoparticle production. The use of plant extracts is a straightforward method for manufacturing nanoparticles on a large scale among the existing green ways of synthesis for metal/metal oxide nanoparticles, as opposed to bacterial and fungal assisted synthesis [3].

**Strategic approaches for the synthesis of nanomaterials:**

**Top-down and Bottom-up Approaches**

Based on the method of nanoparticle creation, green nanoparticle synthesis is divided into two categories: "top-down" and "bottom-up." The dimension of nanoparticles was bigger in the "top-down" approach, thus a mechanical method or acid additions were required to reduce the particle size of the nanoparticles [4]. In general, top-down analysis (thermal decomposition method, mechanical method/ball-milling method, lithographic methods, laser ablation, sputtering) is required. The bulk material is broken down into nanosized structures or particles using the top-down approach. Techniques for making top-down synthesized particles are an advancement of those used to make micron-sized particles. Top-down methods rely on bulk material removal, division, or bulk manufacturing process reduction to produce the desired structure with sufficient qualities. These methods are fundamentally easier.

 The "bottom-up" technique differed from the top-down procedure in that it began at the atomic level by generating molecules Bottom-up approaches are used [5]. The 'bottom-up' approach, on the other hand, has the potential to result in less waste and be more cost-effective. Atom by atom, molecule by molecule, or cluster by cluster creation of a material is referred to as a bottom-up technique. In order to manufacture nanopowder, several of these methods are still under research or are only now being used commercially [6]. The oraganometallic chemical method, the revere-micelle approach, sol-gel synthesis, colloidal precipitation, hydrothermal synthesis, template assisted sol-gel, electrodeposition, and others are a few well-known bottom-up processes for the production of light nanoparticals. To create nanomaterials with the proper size, shape, and orientation, a variety of techniques have been researched [7].

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 **Fig.1 Nanoparticle synthesis method**

#### Other conventional methods:

The size of the material is reduced using a variety of physical techniques, such as ultrasonification, microwave (MW) irradiation, electrochemical processes, and so forth. In this technique, NPs are integrated via evaporation condensation using a tube heater at barometrical weight [8]. Mechano synthesis, microwave-assisted and hydro(solvo) thermal reactions (as well as their combinations), ultrasound-assisted processes, and UV-irradiation of the reaction system are among the physical techniques currently being considered to satisfy green chemistry requirements, such as not requiring dangerous solvents, preventing pollution, and accelerating synthesis processes. These methods include uncommon ones like magnetic field-assisted synthesis. Solvents and catalysis in green processes, Hydro (solvo) thermal synthesis, Ultrasound-assisted (sonochemical) Synthesis, Magnetic field-assisted Synthesis, and photocatalysis.

The main components of the chemical approach are metallic precursors, stabilizing agents, and reducing agents (both inorganic and organic). Reducing chemical compounds such sodium borohydride, ascorbate, and sodium citrate. The tollens reagent, the polyol process, the elemental hydrogen, and (NaBH4) N,N-dimethylformamide (DMF) with poly(ethylene glycol) Using block copolymers [9]. Physical and chemical techniques are used to create nanoparticles more quickly, resulting in mono-dispersed nanoparticles. They do, however, offer certain benefits and drawbacks, such as cost-effective ways and the generation of some toxic metabolites that are harmful to the environment and biological systems.

**Biological methods**

Despite their slower metal reduction speed, biological techniques may be a more ecologically friendly synthesis route when compared to conventional chemical and physical processes. Although microorganisms might be employed for industrial silver recovery, their studies are still very limited, especially those outlining crucial aspects of biosynthesis; hence this technology is only being investigated on a laboratory scale. Because the microorganisms or extracts serve as both stabilizing and capping agents, the biological synthesis of nanoparticles doesn't require any additional stabilizing agents. The absence of toxic chemicals and contaminants, the control over shape and size, the low cost, biocompatibility, and the abundance of precursors (microorganisms and plants) are all advantages of biological processes [10].

Green synthesis techniques use biological agents such viruses, bacteria, fungi, algae, and plants to make nanoparticles. Since they shouldn't obstruct the usage of synthesized nanoparticles, bacteria, fungi, and viruses used in nanoparticle manufacturing are nonpathogenic in nature [11].

**Microorganisms based synthesis**

Viruses, bacteria, fungi, algae, and plants all contribute to the biological creation of nanoparticles (via their enzymes, proteins, DNA, lipids, and carbohydrates, among other things). Metal-decreasing bacteria have been found to be eco-friendly catalysts for bioremediation and material production. In fact, several metal oxides can be produced by bacteria through respiration mechanisms [12].

**Bacteria**

The most prevalent species in our planet is bacteria. This biogenic method is heavily populated with bacteria by providing environmental conditions such as temperature, pH, pressure, and so on. The performance of metal salts and enzymes is enhanced by the biologically generated nanoparticles' higher catalytic reactivity and bigger specific surface area [13].

In commercial biotechnological applications like bioremediation, genetic engineering, and bioleaching, bacterial species are frequently exploited. Bacteria are key players in the production of nanoparticles because of their capacity to reduce metal ions. Bacterial generation of nanoparticles has gained acceptance due to how easily bacteria can be managed. Aeromonas sp. SH10, Phaeocystis antarctica, Pseudomonas proteolytica, Bacillus amyloliquefaciens, Bacillus indicus, Bacillus cecembensis, Arthrobacter species, Lactobacillus casei, Bacillus cereus, Bacillus amyloliquefaciens, Bacillus indicus [14].

**Yeasts and fungi**

Mycosynthesis of NPs is believed to be more fundamental and straightforward for stable NP generation as compared to bacteria. The bigger biomass and ease of culture, the higher metabolite bioaccumulation, the stronger metal tolerance and absorption capacities, and the higher metal wall binding capacity are only a few of the benefits that fungi have over bacteria. It has been demonstrated that a few enzymes, including electron shuttle quinines, Penicillium sp. reductase, Fusarium oxysporum nitrate reductase and NADPH-reductase, are crucial for NP synthesis [15]. Yeast strains have an advantage over bacteria because they are simpler to handle in the lab, produce a variety of enzymes, and grow quickly when given basic nutrients. There has been some investigation towards the production of metallic nanoparticles with yeast. However, using eukaryotic systems, such as Candida glabrata and S. pombe, was one of the primary methods for exploiting biological material [16].

**Algae**

Algae species as Pterocladia capillacae, Jania rubins, Ulva faciata, and Colpmenia sinus have been used to make silver nanoparticles (El-Rafie et al., 2013). The NPs were spherical and ranged in size from 7 to 20 nm. Researchers have shown that their antibacterial activity is brought on by a blockage of bacterial cell processes brought on by their adhesion to the cell wall. Recent studies have shown that Sargassum longifolium alga-derived silver nanoparticles have antibacterial properties. AgNO3 and aqueous algal extract are combined for one hour, at which point the reaction mixture turns brown. Silver nanoparticles that were polydispersed showed an absorption peak at 440 nm. It has been shown that the pH of the reaction mixture significantly affects the amount of silver produced [17].

**Plants based synthesis**

Despite the fact that plant-extract-based nanoparticle synthesis is a well-known method for biological nanosynthesis, the nature of the nanoparticles produced in this way may end up being polydisperse due to the presence of phytochemicals, and the yield may change depending on the season [18]

**Plants and phytochemicals**

A powerful family of molecules derived from natural resources, mainly plants, are known as phytochemicals. They have shown chemopreventive and chemotherapeutic effects not merely in cancer cell lines and animal models, but also in phase I and phase II clinical studies. Phytochemicals are nonnutritive elements of a plant-based diet that have notable anticarcinogenic and antimutagenic properties (the word "phyto" is derived from the Greek meaning plant). Numerous functions for phytochemicals in the treatment and prevention of cancer exist. The bulk of phytochemicals' mechanisms of action are still unknown, despite substantial advancements in our understanding of the carcinogenic process and the development of preventive/therapeutic benefits of phytochemicals. The bioavailability, toxicology, pharmacodynamics, and pharmacokinetics of the plant component(s) should be investigated. When taken orally, several phytochemicals have lower plasma/serum concentrations. This can be explained by low intestinal absorption, intestinal enzyme breakdown, and/or phase I and/or II detoxifying enzyme metabolization. For instance, crocin has a low intestinal absorption rate, with the bulk of orally administered crocin showing up in rats' feces. Additionally, it is broken down by intestinal enzymes, and crocetin was found in mice's serum two hours after they had oral crocin therapy [19]. Nanoparticles made from plant-related organs like leaves, stems, flowers, bark, roots, seeds, and their metabolites have been used to create biosynthesis. Environmentally friendly NPs stabilizers, non-toxic ion reduction agents, and green biosynthetic solvent medium must all be taken into account [20]. The extract from plant parts such roots, leaves, stems, seeds, and fruits is rich in phytochemicals, which function as both reducing and stabilizing agents, these parts of plants have also been employed in the synthesis of NPs [21].

The green synthesis of NPs using plant leaves has been the subject of numerous studies, but little research has been done on the biosynthesis of NPs using native species that may have anticancer and antibacterial potential. The Cucurbitaceae plant family, which includes the herbaceous perennials Cucurbita, Langenaria, Citrullus, Cucumis, and Momordica, contains over 125 genera and about 960 species [22]. The use of green, or natural and ecologically friendly, reducing and capping agents for the synthesis used plant leaves from the Azadirachta indica (neem), Ocimum tenuiflorum (black Tulsi), Ficus benghalensis (banyan tree), and other species [23].

**Applications:**

 There has been a significant growth in scientific papers in the subject of nanotechnology during the previous decade. Green-synthesized nanomaterials serve important roles in the application of nanotechnology to a wide range of disciplines [24-25]. Green nanotechnology is the creation of green nano-products and their use to promote sustainable development. Green synthesized NPs have important roles in pharmaceuticals, therapeutic applications, and in vitro diagnostics. Green-synthesised nanoparticles have remarkable antibacterial, antifungal, and anti-parasitic properties [26-28].

**Conclusion**

 Recent years have seen the publication of numerous papers on environmentally friendly nanoscale metal production. Micro-wiring, electronics, energy harvesting, food, agriculture, and medicine are just a few of the fields where nanoparticles are helpful. Physical, chemical, and biological processes can all produce nanoparticles. Green synthesis techniques seem to be more effective and successful than similar technologies. The green synthesis method is safe for the environment, non-toxic, and economical. These studies significantly supported the use of green synthesis techniques to produce metal and metal oxide nanoparticles that respond better in environmental and therapeutic applications. Our study team intends to create a variety of green nanoparticles in the future for usage in a range of industries, including pharmaceutical, medical, environmental, aquaculture, and agricultural. The results of this study lead the way for further research on the creation of green nanoparticles for use in the environmental and biomedical fields.

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