

GREEN SYNTHESIS OF NANOPARTICLES

Abstract

As the globe becomes greener, eco-friendly practices that protect the environment for coming 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 its major advantages and applications.

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

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I. INTRODUCTION

Due to 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 synthesize 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. Green synthesis was developed as a solution to these issues; it decreases metal ions by using plant extracts rather than synthetic chemical agents. Recent years have seen a rise in interest in the green production of metallic nanoparticles. Green synthesis of nanoparticles has gained popularity in recent years due to its speed, low cost, capacity to synthesize nanoparticles with good stability in a short amount of time, ability to create non-toxic byproducts, and environmental friendliness. Additionally, it is simple to scale it up for large-scale synthesis [2]. Many different microorganisms, including bacteria, fungi, and yeast, as well as plants, have been used to produce metal nanoparticles. To avoid the production of unwanted or dangerous by-products, "green synthesis" is necessary. This is accomplished through developing dependable, durable, and eco-friendly synthesis procedures. It is essential for reaching this purpose to make use of the appropriate natural resources, such as organic systems, and solvent systems. Different biological elements, such as bacteria, fungi, algae, and plant extracts, have been incorporated using green metallic nanoparticle production. As an easy alternative to bacterial and fungal-aided synthesis, the utilization of plant extracts is a viable strategy for producing nanoparticles on an environmentally friendly, large scale [3].

II. STRATEGIC APPROACHES FOR THE SYNTHESIS OF NANOMATERIALS

1. Top-down and Bottom-up Approaches: Green nanoparticle synthesis is classified into two methods: "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 (using techniques like sputtering, laser ablation, mechanical procedures like ball milling, and thermal decomposition) is needed. Using the top-down method, the bulk material is broken down into nanosized structures or particles. Top-down synthesized particle production methods are an improvement over micron-sized particle production methods. The desired structure with the necessary attributes is created using top-down approaches by removing bulk materials, dividing them, or reducing bulk production processes. Fundamentally, these techniques are simpler.

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]. On the other side, the 'bottom-up' strategy might produce less waste and be more economical. A bottom-up approach is when a substance is created atom by atom, molecule by molecule, or cluster by cluster. To manufacture nanopowder, several of these methods are still under research or are only now being used commercially [6]. The organometallic chemical method, the reverse-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 nanoparticles. To create nanomaterials with the proper size, shape, and orientation, a variety of techniques have been researched [7].

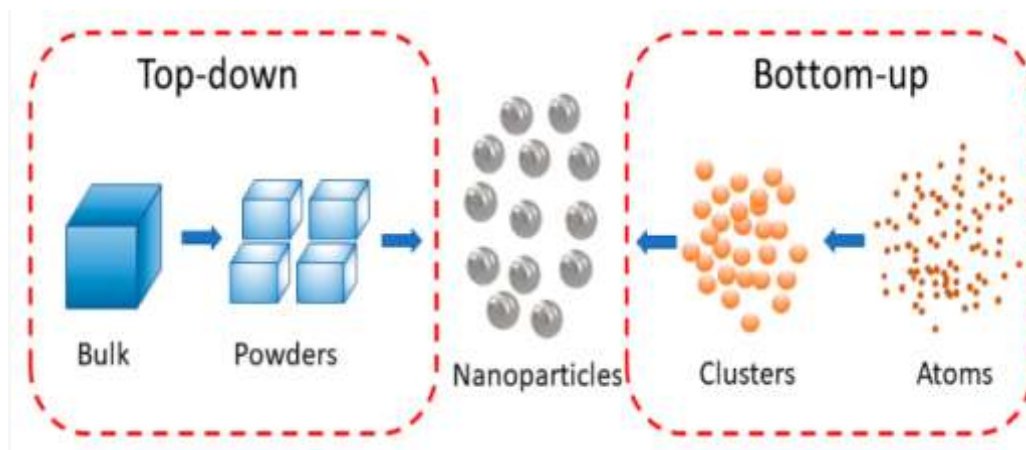


Figure 1: Nanoparticle Synthesis Method

- 2. Other Conventional Methods:** The size of the material is reduced using a variety of physical techniques, such as ultrasonication, 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(solve) thermal reactions (as well as their combinations), ultrasound-assisted processes, and UV-irradiation of the reaction system are some of the physical techniques currently being considered to satiate the needs of green chemistry, such as not requiring hazardous solvents, preventing pollution, and speeding up synthesis processes. Among these are novel techniques like magnetic field-assisted synthesis. solvents and catalysis in environmentally friendly procedures, hydrothermal (solvo) synthesis, sonochemical synthesis assisted by ultrasound, magnetic field synthesis assisted by magnetism, 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 as sodium borohydride, ascorbate, and sodium citrate. The tollens reagent, the polyol process, the elemental hydrogen, and $(\text{NaBH}_4)\text{N}$, 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.

III. 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].

To create nanoparticles, green synthesis approaches involve biological agents such as viruses, bacteria, fungi, algae, and plants. Since they shouldn't obstruct the usage of synthesized nanoparticles, bacteria, fungi, and viruses used in nanoparticle manufacturing are nonpathogenic [11].

- 1. 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 are eco-friendly catalysts for bioremediation and material production. Several metal oxides can be produced by bacteria through respiration mechanisms[12].
- 2. Bacteria:** The most prevalent species on 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].

Bacterial species are frequently used in commercial biotechnological processes such as bioremediation, genetic engineering, and bioleaching. 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. *Phaeocystis Antarctica*, *Aeromonas* species, and *SH10 Falciparum proteolytica*, *Bacillus indicus*, *Bacillus cecembensis*, and *Bacillus amyloliquefaciens* species of *Arthrobacter*, *Bacillus cereus*, *Bacillus amyloliquefaciens*, *Lactobacillus casei*, and *Bacillus indicus* [14].

- 3. Yeasts and Fungi:** Psychosynthesis 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 into the production of metallic nanoparticles with yeast. One of the most common ways to utilize biological material, nevertheless, was by employing eukaryotic systems like *Candida glabrata* and *S. pombe* [16].
- 4. Algae:** According to El-Rafie et al. (2013), silver nanoparticles have been produced using the algae species *Pterocladia capillacea*, *Jania rubins*, *Ulva faciata*, and *Colpomenia sinus*.

The NPs had spheres and were between 7 and 20 nm in size. Researchers have established that the blocking of bacterial cell processes caused by their adherence to the cell wall is what causes their antibacterial activity. Silver nanoparticles generated from the *Sargassum longifolium* alga have antimicrobial qualities, according to recent studies. After one hour of reaction time, the mixture of AgNO₃ and aqueous algal extract turns brown. Polydispersed silver nanoparticles 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].

5. **Plants Based Synthesis:** Although the production of plant-extract-based nanoparticles is a well-known technique for biological nanomaterials synthesis, 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]
6. **Plants and Phytochemicals:** A powerful family of molecules derived from natural resources, mainly plants, are known as phytochemicals. Not only in cancer cell lines and animal models but also in phase I and phase II clinical investigations, they have demonstrated chemopreventive and chemotherapeutic activities. The non-nutritive components of a plant-based diet known as phytochemicals are well-known for their anticarcinogenic and antimutagenic qualities (the word "phyto" is derived from the Greek word for 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 metabolism. 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]. Bio-synthesis has been utilized to produce nanoparticles manufactured from plant-related organs such as leaves, stems, flowers, bark, roots, seeds, and their metabolites. Environmentally friendly NPs stabilizers, non-toxic ion reduction agents, and green biosynthetic solvent medium must all be taken into account[20]. Phytochemicals, which serve as reducing and stabilizing agents, are abundant in the extract from plant parts such as roots, leaves, stems, seeds, and fruits. These plant components have also been used 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), *Ocimumtenuiflorum* (black Tulsi), *Ficus benghalensis* (banyan tree), and other species[23].

IV. APPLICATIONS

There has been a significant growth in scientific papers on 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-synthesized nanoparticles have remarkable antibacterial, antifungal, and anti-parasitic properties [26-28].

V. 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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