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Invited Review

# A review on biogenic synthesis of ZnO nanoparticles using plant extracts and microbes: A prospect towards green chemistry

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ABSTRACT

Nanotechnology is emerging as an important area of research with its tremendous applications in all fields of science, engineering, medicine, pharmacy, etc. It involves the materials and their applications having one dimension in the range of 1–100 nm. Generally, various techniques are used for syntheses of nanoparticles (NPs) viz. laser ablation, chemical reduction, milling, sputtering, etc. These conventional techniques e.g. chemical reduction method, in which various hazardous chemicals are used for the synthesis of NPs later become liable for innumerable health risks due to their toxicity and endangering serious concerns for environment, while other approaches are expensive, need high energy for the synthesis of NPs. However, biogenic synthesis method to produce NPs is eco-friendly and free of chemical contaminants for biological applications where purity is of concerns. In biological method, different biological entities such as extract, enzymes or proteins of a natural product are used to reduce and stabilised formation of NPs. The nature of these biological entities also influence the structure, shape, size and morphology of synthesized NPs. In this review, biogenic synthesis of zinc oxide (ZnO) NPs, procedures of syntheses, mechanism of formation and their various applications have been discussed. Various entities such as proteins, enzymes, phytochemicals, etc. available in the natural reductants are responsible for synthesis of ZnO NPs.



## 1. Introduction

Nanotechnology is emerging as a new field of research dealing with synthesis of NPs and nanomaterials for their applications in various fields such as electrochemistry, catalysis, sensors, biomedicines, pharmaceutics, health care, cosmetics, food technology, textile industry, mechanics, optics, electronics, space industry, energy science, and optical devices, etc. [1–7]. The particles whose size lies in the dimension area of 1–100 nm are called nanomaterials, and these materials are found to show enhanced properties based on size, distribution and morphology [8]. Among the nanomaterials used in aforesaid arenas, metal NPs and metal oxide NPs are considered as most efficient as these contain remarkable enhanced properties such as antimicrobial properties due to their increase surface area to volume ratio [9]. These NPs find their applications in various fields of science and engineering such as in electrochemistry, catalysis, medical devices, cleaning agents, textile industry, etc. [10,11].

From the past decade, nanoparticles have also been increasingly modified or engineered for the industrially manufactured items such as cosmetics, textiles and electronics. Additionally, as there is requisite of novel medicines as well as function of nanoparticles in biological components of living cells, nanoparticles have been applied to diverse medical fields. Recently, nanoparticles have been tested for molecular imaging to accomplish highly resolved images for diagnosis. Biomarkers, drug discovery and molecular diagnostics could be applicable to the patients in cardiovascular and oncology medicine. Furthermore, contrast agents have also been encumbered onto nanoparticles for the diagnosis of tumour and atherosclerosis [12]. Besides this, nanotherapeutic have been marketed all over the world after first FDA approved nanotherapeutic in 1990, in order to develop multiple nano-based medicines. However, the intricacy regarding ideal properties is inherent with any therapeutic research, especially one as novel and relatively progressive. But positive epidemiological studies provide rationale for the development of nano-based pulmonary therapeutics [13].

## 2. Biogenic Production of NPs and Prospect Towards Green Chemistry

Generally NPs are synthesized by various physical or chemical techniques (Fig. 1), such as sputtering, milling, nanosphere lithographic technique, chemical reduction, etc. [14]. These conventional techniques used for synthesis of metal NPs are quite expensive and hazardous to

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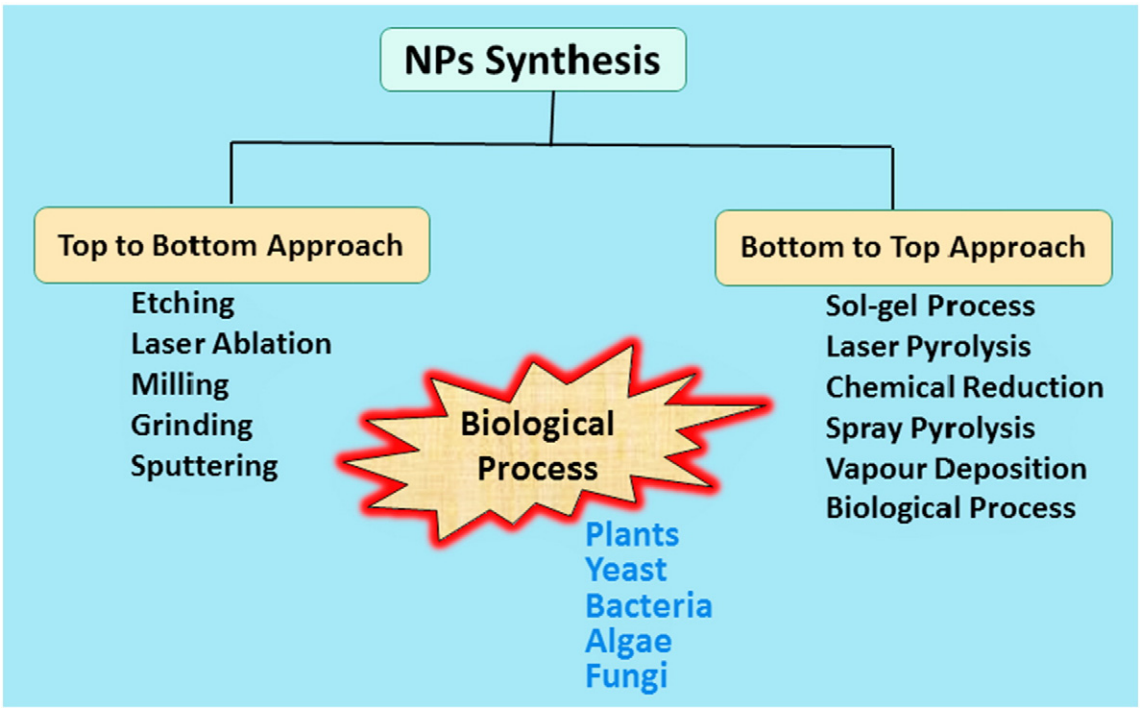


**Fig. 1.** Various approaches of synthesis of NPs.

environment due to involvement of various perilous and hazardous chemicals in their synthesis responsible for various health risks [15]. During the last decade, researchers showed their interest to biological method involved in synthesis of metal and metal oxide NPs, and the development of this biologically inspired technique is evolving as an important branch in the field of nanotechnology and nanoscience [16]. In the biological synthesis method (importance is mentioned in Fig. 2), the use of plant extracts, fungi, microbes, and raw materials of fruits and vegetables are used for synthesis of metal and metal oxide NPs [14,16]. The various types of NPs have been synthesized by using this green and eco-friendly way using plants extract and microbes, etc. [17–20]. The morphological structure of NPs plays an important role in controlling chemical, physical, and optical properties, etc.

Among metal and metal oxide NPs, ZnO and silver NPs are of much interest in scientist community due to their excellent properties for their use in different areas such as antimicrobial, catalytic and optical properties [21,22]. Depending upon the morphology of ZnO NPs, it showed different physical and chemical properties. ZnO NPs are synthesized by different techniques such as laser ablation, hydrothermal methods, electrochemical depositions, sol–gel method, chemical vapor deposition, thermal decomposition, and combustion method, ultrasound, microwave-assisted combustion method, co-precipitation, and electrophoretic deposition [23–25]. Recently, ZnO NPs are also synthesized by biological method using biological agents as reducing agents [26]. ZnO NPs are non-toxic, semi-conducting materials having high transparency and good photocatalysis (Fig. 3).

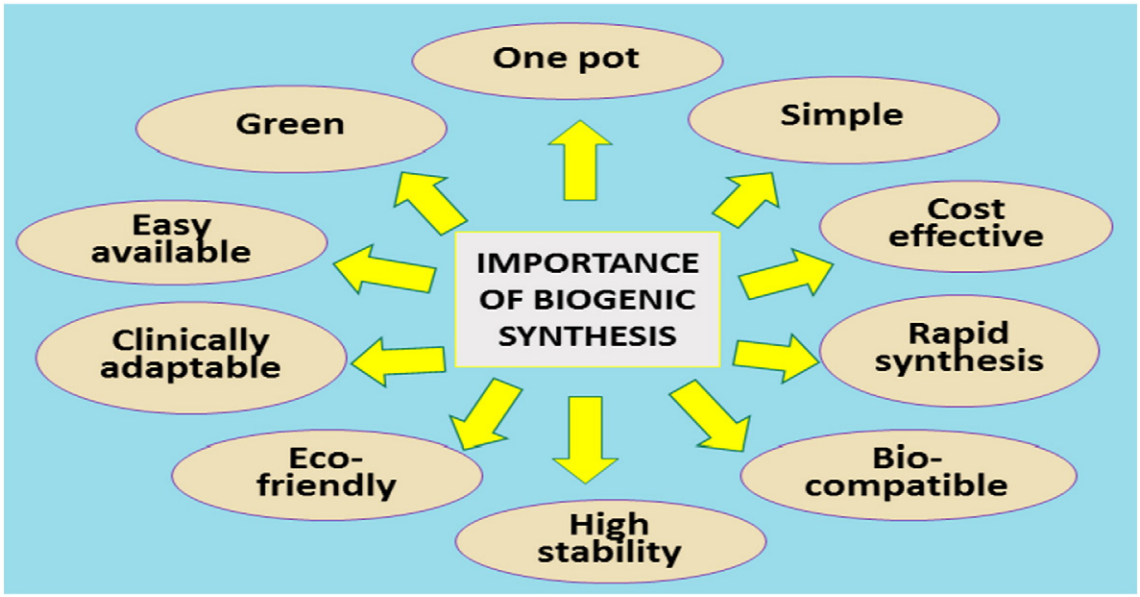


**Fig. 2.** Importance of biogenic synthesis of NPs.