

## A Review on Green Synthesis, Characterization and Antibacterial Activity of Nanoparticles

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### Abstract

The extensive use of synthetic materials in nanoparticle manufacturing has led to an increase in environmental pollution. Green synthesis has emerged as a viable alternative due to its utilization of biodegradable components. This study focused on employing plant extracts as natural precursors for the green synthesis, characterization, and antibacterial evaluation of nanoparticles.

### Introduction

Nanotechnology has the potential to bring about many advancements and is the basis for continuing research in a number of sectors. The method used to create applications that use engineered materials with a minimum size of one nanometre is called this [1]. Nano-materials are structural entities that are 1 to 1000 nanometers long and are made up of smaller groupings of particles called nanoparticles (NP), which are 1 to 100 nanometers long [2]. Nanoparticles come in many different shapes and sizes, like cones, spirals, flat shapes, and hollow shapes. They have physical attributes that are better than those of larger particles, such as greater stability and strength. They are frequently employed, signifying that they possess characteristics advantageous in several situations [3, 4].

Nanoparticles (NPs) are materials possessing at least one dimension within the nanometre scale (1-100 nm). Their size-dependent properties have enabled many applications across multiple domains, including medicine, electronics, and catalysis. Traditional methods for making NP use dangerous chemicals and high temperatures,

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which can be bad for the environment and workers. Green synthesis methods have been established as feasible options to mitigate these challenges. These solutions utilize biological entities (i.e., plants, microbes, and enzymes) to synthesize nanoparticles in a more environmentally sustainable manner.

### **Different kinds of NPs**

We put NPs into groups based on their size, shape, activity, and the materials they are formed of. This is a quick list of how NPs are sorted according on what they're formed of. Nanoparticles come in two main types: organic and inorganic. Inorganic nanoparticles (NPs) comprise carbon-based nanoparticles, metal and metal oxide nanoparticles, semiconducting nanoparticles, and ceramic nanoparticles. Organic NPs, on the other hand, fall into two groups: polymeric NPs and nanoparticles made from biomolecules [5].

### **General Attributes**

Almost all kinds of nanomaterials and nanoparticles have these traits in common. Actually, a lot of NP applications are based on these characteristics.

### **The Sizes of Nanoparticles**

The size of nanoparticles has a big effect on their qualities and the ways they are meant to be used. The process of making the nanoparticles and the parameters of the reaction have a big effect on their size, which in turn affects how well they work in different applications. Iron oxide nanoparticles (iron oxide NPs) made during hydrothermal synthesis were quite crystalline and had a combination of the crystalline phases magnetite and maghemite. The proportion of the maghemite phase relative to magnetite increased with the size of the nanoparticles, reaching complete purity at a particle size of 123.44 nm. Analysis using transmission electron microscopy indicated that the nanoparticle size increased from 14.54 nm to 29.99 nm as the reaction temperature increased from 100 °C to 180 °C. Similarly, extending the reaction duration from 1 to 48 hours at 180 °C resulted in an increase in nanoparticle size from 20.66 nm to 123.44 nm after 12 hours [6]. Gold nanoparticles with dimensions less than 10 nm were synthesized, and their optical properties were assessed [7]. The size of Au nanoparticles markedly affects their optical properties and potential applications. The antibacterial efficacy of Ag NPs against various bacterial strains depended on their size and morphology [8].

The sizes of the nanoparticles have a big impact on how they can be used. A tunneling ultra-microelectrode (TUME) measuring 1-40 nm or larger was used to make an electrode by helping a single platinum nanoparticle (Pt NP) grow and nucleate on its surface. It improved mass transfer and made it easier to find the electron transfer parameters for quick ET reactions [9]. The differences in the sizes of iron oxide nanoparticles have an effect on the band gap and strain [10].

### **The NPs' Shape**

In addition to nanoparticle size, form and structure play significant roles in various technical applications. The regulation of synthesis parameters to control nanoparticle morphology has been addressed to varying degrees. As a result, nanoparticles of identical materials can be synthesized in various shapes to meet particular applications. Nanoscience includes a recognized area of research focused on the shape-controlled synthesis of nanoparticles. The influence of surface area and structural characteristics of catalysts on the electrocatalytic activity of electrochemical reactions is widely acknowledged, and catalysts based on nanoparticles are no exception to this principle. In the context of oxygen reduction within an acidic electrolyte, octahedral cobalt disulphide nanoparticles, meticulously shaped and supported on composites of nitrogen- and sulfur-doped graphene and carbon nanotubes, were employed [11]. The deliberate adjustment of surfactant use during the synthesis process led to the successful creation of a wide range of TiO<sub>2</sub> nanoparticles and nanorods with spherical, cubic, elliptical, and nanorod shapes. The photocatalytic activity demonstrated a significant reliance on the morphology [12]. Different methods have been used to make Se nanoparticles, which can take the form of nanowires, nanoribbons, nanoplates, nanotubes, and nanospheres. The primary focus of research on spherical Se NP is on biological processes. A self-assembly method was recently utilized to produce cubic-like selenium nanoparticles (SeNPs), and their anticancer activity was assessed in relation to the impact of the SeNPs' morphology on this activity [13]. The dimensions and structural characteristics substantially affect the manufacturing process. Recent studies on solar photocatalysts using ZnO nanoparticles have explored the fabrication process and its impact on the final morphology and dimensions of the particles [14].

### **The Nanoparticles' Surface Area**

Because nanoparticles have large surface areas, they are used in a lot of different ways, including catalysis, adsorption, electrochemical reactions, reactivity, and many others. We used a hydrothermal approach to make superparamagnetic ascorbic acid-coated Fe<sub>3</sub>O<sub>4</sub> nanoparticles.

These nanoparticles have a tiny diameter and a large specific surface area of 179 m<sup>2</sup>/g. The nanoparticles were used to adsorb heavy metals and showed a high capacity for doing so [15]. The synthesis process and experimental conditions significantly affect the surface area of resultant nanoparticles and their functionality in specific contexts [16].

### **Distinctive Features Specific to Certain Types of Nanoparticles**

Not all nanoparticles exhibit these characteristics, as specific properties, including optical, magnetic, and antibacterial capabilities, are linked to particular types of nanoparticles. This section will briefly examine specific traits of NP.

#### **Light Attributes**

The optical properties of metal nanoparticles have attracted considerable attention in the scientific community, with applications originating in the mid-19th century [17]. The literature extensively investigates the optical characteristics of Au NPs, primarily ascribed to surface plasmon resonance phenomena, which exhibit unique and adjustable optical properties. This phenomenon further enhances surface-enhanced luminescence, surface-enhanced Raman scattering (SERS), Mie scattering, and surface plasmon absorption. They exhibit high quality, produce various shapes and combinations, and are easy to synthesize. Furthermore, their biocompatibility makes them appropriate for therapeutic applications [18]. Nanoparticle surfaces can be readily functionalized with various proteins, antibodies, and ligands to target cancer-related biomarkers on cancer cells. This function ensures precision at the molecular level. Besides diagnoses, they provide advantages regarding therapeutic options. Selective photothermal therapies for malignancy have been utilized alongside suitable immunological targeting methods. The Au NPs' surface-intensive Plasmon absorption is followed by a rapid photothermal transformation. Au NPs can be optically tuned to operate in the near IR region by transitioning from spherical to nanorod shapes. This attribute is exceedingly advantageous for in vivo imaging and therapy [18]. Also, Gold NPs have been utilised as labels in the lateral flow assay method [19].

The particle size and interparticle spacing of Au-NPs influence their color and peak absorption wavelength. These attributes have been extensively utilized by colorimetric sensors to detect various analytes in biological, nutritional, and environmental specimens. These strategies are straightforward, rapid, responsive, and suitable for circumstances requiring prompt observation and effective problem-solving [20]. In addition to Aurate nanoparticles, various noble metals,

metal oxides, and metal sulfide nanoparticles have demonstrated luminescent characteristics and, consequently, similar applications [21]. The optical characteristics of nanoparticles are affected by their dimensions and aggregation state.

### **Magnetic Qualities**

Magnetic fields can manipulate a certain type of nanoparticles referred to as magnetic nanoparticles. Typically, they consist of a chemically advantageous substance and a magnetic element. Chemically functional materials, including iron, nickel, and cobalt, may be chosen or synthesized for the magnetic material according to the application. Post-field cooling, magnetic nanoparticles (NPs) exhibit distinctive novel singularities, such as shifting loops, high field irreversibility, saturation field, super-paramagnetism, and additional anisotropic contributions. Surface effects and narrow, finite-size effects, which govern the magnetic behavior of individual nanoparticles, are the underlying causes of these phenomena. Magnetic nanoparticles (NPs) are utilized in electrochemical immunoassays to isolate analytes from samples and subsequently transfer them to the electrode using magnetic or immuno-specific means due to their separation capabilities [22].

### **Anti-microbial characteristics**

Many NPs have been used as antibacterial agents because of their exceptional antibacterial properties. The cytotoxicity and interactions of ZnO nanoparticles with cells, tissues, and biomolecules have been investigated due to their significant biocompatibility. They possess significant antibacterial potential and participate in chemical and physical interactions with bacterial cells. Nanoparticles interact physically by mechanical damage, cellular internalization, or rupture of cell membranes, resulting in the production of H<sub>2</sub>O<sub>2</sub>, chemically released Zn<sup>2+</sup> ions, and photo-induced reactive oxygen species, which collectively provide antimicrobial properties. A review asserts that the impact of various ZnO nanomaterial morphologies is addressed [23].

In order to guarantee the appropriate activation and distribution of nanoparticles, a diverse array of polymeric materials, in addition to metal and metal oxide nanoparticles, are employed in conjunction [24]. According to reports, a significant number of hospital-acquired illnesses are transmitted through contaminated surfaces or catheters, which are frequently formed of plastic. Numerous polymers are employed in the fields of biology and healthcare. The incorporation of anti-microbial nanoparticles into these polymer matrices may enhance their ability to prevent the transmission of diseases within the materials [25].

## **Syntheses of Nanoparticles in a Green Way**

Biological material helps nanoparticles stay stable and lowers their size in a way that is good for the environment. Plant extracts have garnered significant interest because to their abundant phytochemical composition, which demonstrates capping and lowering capabilities. Alkaloids and phytochemicals, including flavonoids and terpenoids, can chemically bond with metal ions to make nanoparticles. The procedure entails the integration of a metal salt solution into a plant extract, which promotes the reduction of metal ions to nanoparticles (NPs) and enables the plant extract to stabilize the NPs [4].

## **Characterization Techniques**

The synthesized nanoparticles are characterized through various techniques, including:

- UV-Visible Spectroscopy employs the surface plasmon resonance (SPR) band, a characteristic peak associated with metallic nanoparticles, to track the formation of nanoparticles.
- Transmission Electron Microscopy (TEM): TEM provides details on the size, shape, and morphology of NPs.
- Dynamic light scattering (DLS) is employed to conduct size distribution experiments and determine the zeta potential of NPs.
- FTIR: Fourier Transform Infrared Spectroscopy: IR analysis can ascertain the functional groups that contribute to the stabilization and reduction of NPs.
- X-ray diffraction (XRD): This technique verifies the NPs' crystalline phase and phase purity.

## **Antibacterial Activity of Nanoparticles**

Nanoparticles, particularly metallic nanoparticles like silver and copper, possess substantial antibacterial properties. The methods of action are diverse and include [4]:

- Membrane disruption: Nanoparticles have the capacity to disrupt the membrane of bacteria, resulting in the demise of the bacterial cell.

- Oxidative stress: The capacity of reactive oxygen species (ROS) generated by nanoparticles to cause damage to cellular constituents is a concern.
- DNA damage: The attachment of NPs to bacterial DNA can impede replication and result in DNA damage.

### **Applications of Green-Synthesized Nanoparticles**

These green-synthesized nanoparticles have a wide range of potential applications, including:

- Medicine: antimicrobials, medication administration, cancer treatment, and wound care.
- Environmental remediation: Pollutant removal and water purification.
- Agriculture: Crop improvement and plant disease prevention.
- Electronics: catalysts and sensors.

### **Conclusion**

The eco-friendly synthesis of nanoparticles provides a sustainable and environmentally safe alternative for nanomaterial fabrication. The use of biological materials as reducing or stabilizing agents obviates the necessity for toxic chemicals and high temperatures, hence promoting an environmentally benign process. Synthesized nanoparticles demonstrate substantial antibacterial properties, rendering them suitable for diverse biological applications. To optimize the production process, the long-term stability of nanoparticles must be assessed, along with their biocompatibility and toxicity.

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