Journal of Harbin Engineering University
ISSN: 1006-7043
Vol 44 No. 11
November 2023

Green Nanoparticle Production and Its Potential Applications

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Abstract: Nanotechnology is a very new and growing technology with numerous uses. It entails the production and utilisation of materials with dimensions ranging from 1 to 100 nm. Nowadays, a wide range of physicochemical techniques are employed to synthesise nanoparticles (NPs). However, biogenic reduction of metal precursors to produce matching NPs is more environmentally friendly, less expensive, and free of chemical impurities for medical and biological applications where NP purity is critical. Biogenic reduction, like chemical reduction, is a "Bottom Up" technique in which a reducing agent is replaced by an extract of a natural substance with inherent stabilising, growth terminating, and capping capabilities. Furthermore, the size and shape of NPs are influenced by the nature of biological entities in varied concentrations in combination with reducing chemical agents. The current review focuses on the green synthesis of Ag, Au, Cu, Fe, Pd, Ru, PbS, CdS, CuO, CeO2, Fe3O4, TiO2, and ZnO NPs using microorganisms or plants, as well as their prospective applications.
Keywords: green method, nanoparticle synthesis, AgNPs, FTIR

Introduction:

Nanoparticles (NPs) with dimensions ranging from 1-100 nm serve as a link between bulk materials and atomic or molecular structures (Kaushik et al. 2010). Because of their small size, huge surface area with free dangling bonds, and higher reactivity than their bulk counterparts (Kubik and Sugisaka 2002; Daniel and Astruc 2004; Zharov et al. 2005), they have surprising and fascinating features. Scientists have been aware of biological organisms' potential to decrease metal precursors since the nineteenth century, but the methods remain unknown.

The advancement of efficient green synthesis that employs natural reducing, capping, and stabilising agents without the need of hazardous, expensive chemicals and high energy consumption has drawn researchers to biological approaches (Mukherjee et al. 2001;

Rapid industrialization, urbanisation, and population growth are causing the earth's atmosphere to deteriorate and a massive number of toxic and undesired compounds to be discharged. It is now imperative to learn about the secrets hidden in nature and its natural products, which will lead to breakthroughs in the synthesis of NPs. Furthermore, NPs are commonly used in human contact regions, and there is a rising need to develop synthesis procedures that do not rely on severe hazardous chemicals. As a result, green/biological NP synthesis is a viable alternative to chemical and physical approaches.

Green production of nanoparticles and their impacts:

Green production of nanoparticles refers to the use of environmentally friendly and sustainable methods for synthesizing nanoparticles. These methods aim to minimize the use of hazardous materials, reduce energy consumption, and decrease waste generation, thus reducing the environmental impact associated with nanoparticle production.

There are several benefits and impacts of green production of nanoparticles:

1. Environmental Sustainability: Green synthesis methods often use natural and renewable resources, such as plants, bacteria, or fungi, as reducing agents or templates for nanoparticle synthesis. This reduces the dependency on toxic chemicals and energy-intensive processes, making nanoparticle production more sustainable and environmentally friendly.

2. Reduced Waste and Pollution: Traditional nanoparticle synthesis methods often involve the use of toxic chemicals and generate hazardous by-products. Green synthesis methods minimize or eliminate the use of such chemicals, resulting in reduced waste generation and lower environmental pollution.

3. Cost-effectiveness: Green synthesis methods typically use inexpensive and readily available raw materials, reducing the overall production costs.

This makes green production of nanoparticles economically viable, especially for large-scale applications.

4. Biocompatibility: Green-synthesized nanoparticles tend to exhibit higher biocompatibility compared to nanoparticles produced using traditional methods, as they are often derived from naturally occurring substances. This makes them suitable for various biomedical applications, including drug delivery, imaging,and tissue engineering.

5. Potential for Tailored Properties: Green synthesis methods offer the flexibility to tune nanoparticle properties, such as size, shape, and surface functionality, by varying the synthesis conditions and using different biological templates or reducing agents. This allows for the production of nanoparticles with specific characteristics optimized for various applications.

6. Potential for Nanoparticle Recovery and Recycling: Some green synthesis methods allow for the recovery and recycling of nanoparticles, further reducing waste and environmental impact. For example, nanoparticles synthesized using biological templates can be easily separated and reused for subsequent synthesis cycles.

However, it is important to note that while green production methods offer numerous advantages, they also pose challenges. The scalability and reproducibility of green synthesis methods can be more challenging compared to traditional methods. Additionally, the characterization and standardization of nanoparticles produced through green synthesis may require further development to ensure consistent quality and performance.

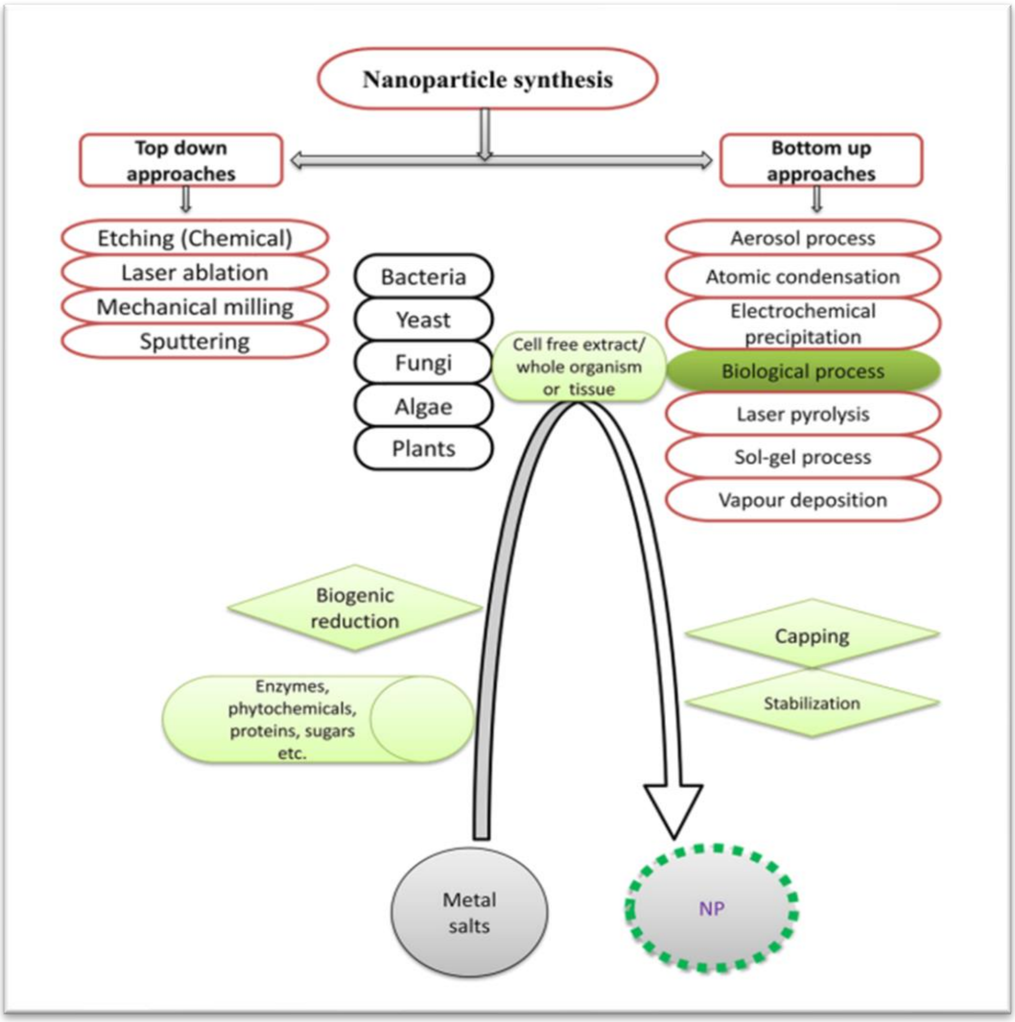

Fig. 1 A generalised flow chart of multiple physicochemical techniques to nanoparticle synthesis, with a focus on biological synthesis.

1. Selection of Biological Agent: Choose a biological agent such as bacteria, fungi, plants, or their extracts that have the potential to act as a template, reducing agent, or stabilizing agent for nanoparticle synthesis.
2. Pre-treatment: Pre-treat the biological agent by washing, grinding, or drying, depending on the nature of the chosen agent. This step helps to remove impurities and enhance their effectiveness in nanoparticle synthesis.
3. Preparation of Precursor Solution: Prepare a precursor solution containing metal salts or other chemicals suitable for nanoparticle formation. Consider the desired nanoparticle composition and choose appropriate precursor materials accordingly.
4. Mixing and Reaction: Combine the biological agent (template/reducing agent) with the precursor solution and allow them to undergo a reaction. This step can often be done under ambient conditions or mild reaction conditions, depending on the biological agent and desired nanoparticle properties.
5. Particle Characterization: After the reaction, characterize the synthesized nanoparticles using analytical techniques such as transmission electron microscopy (TEM), scanning electron microscopy (SEM), X-ray diffraction (XRD), or spectroscopy methods. This step helps to determine the size, shape, crystallinity, and composition of the nanoparticles.

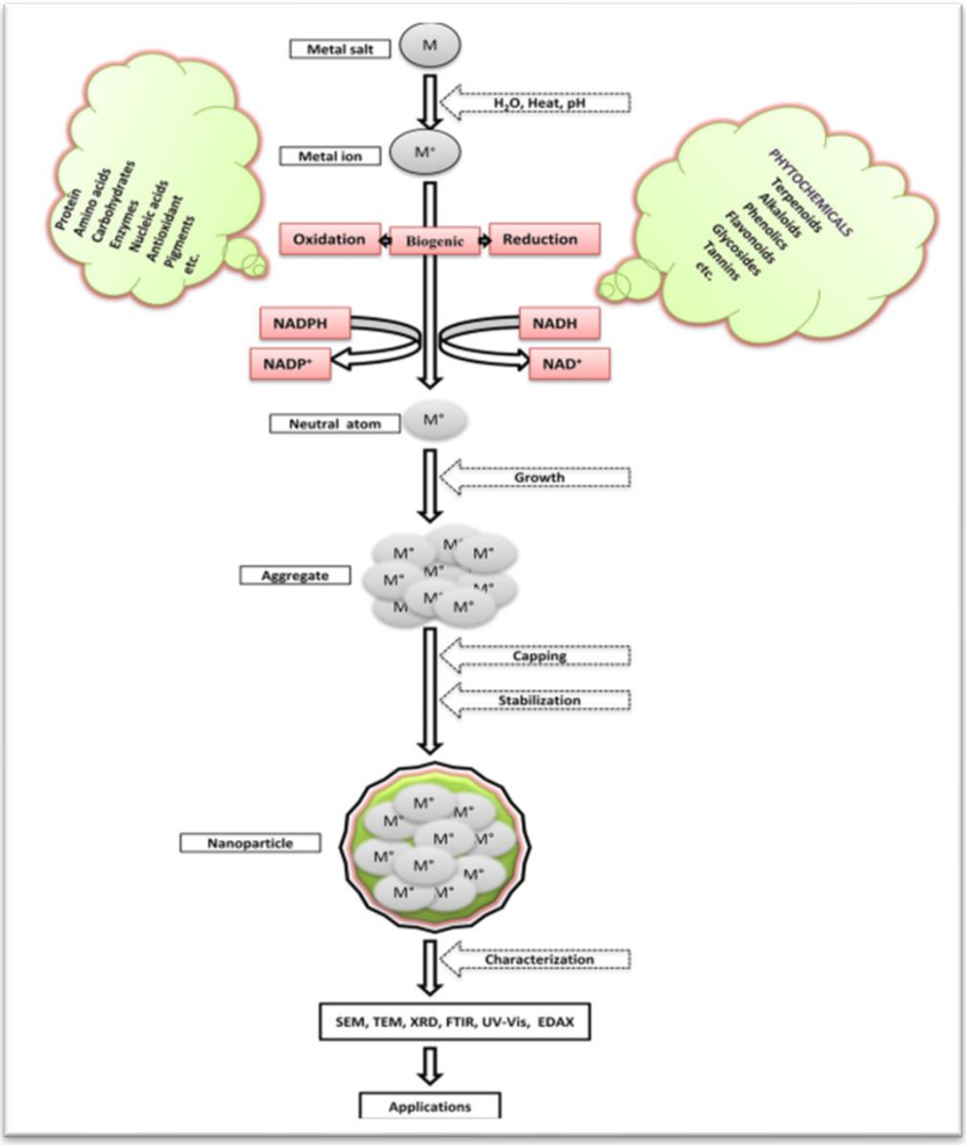

Fig. 2 Diagram summarising the possible method of physiologically mediated nanoparticle creation. Mo neutral atom, M metal salt, M? metal ion

1. Selection of Organism: Choose an organism known for its ability to synthesize or accumulate nanoparticles. For example, some bacteria, such as Shewanella oneidensis or Geobacter sulfurreducens, have the capacity to convert metal ions into metallic nanoparticles.
2. Culturing and Growth: Establish a suitable growth medium for the selected organism and subject it to optimal growth conditions to promote its activity in nanoparticle synthesis. This typically includes providing the necessary nutrients, pH, temperature, and oxygen levels.
3. Introduction of Precursor: Introduce the precursor material, which contains the desired metal ions or compounds, into the growth medium. The selected organism interacts with the precursor and facilitates the conversion of these components into nanoparticles.
4. Biotic Synthesis Process: Under specific physiological conditions, the organism takes up the metal ions and enzymatically or biochemically reduces them to form nanoparticles. The organism may also excrete organic compounds or proteins that act as capping agents, controlling the size, shape, and stability of the nanoparticles.

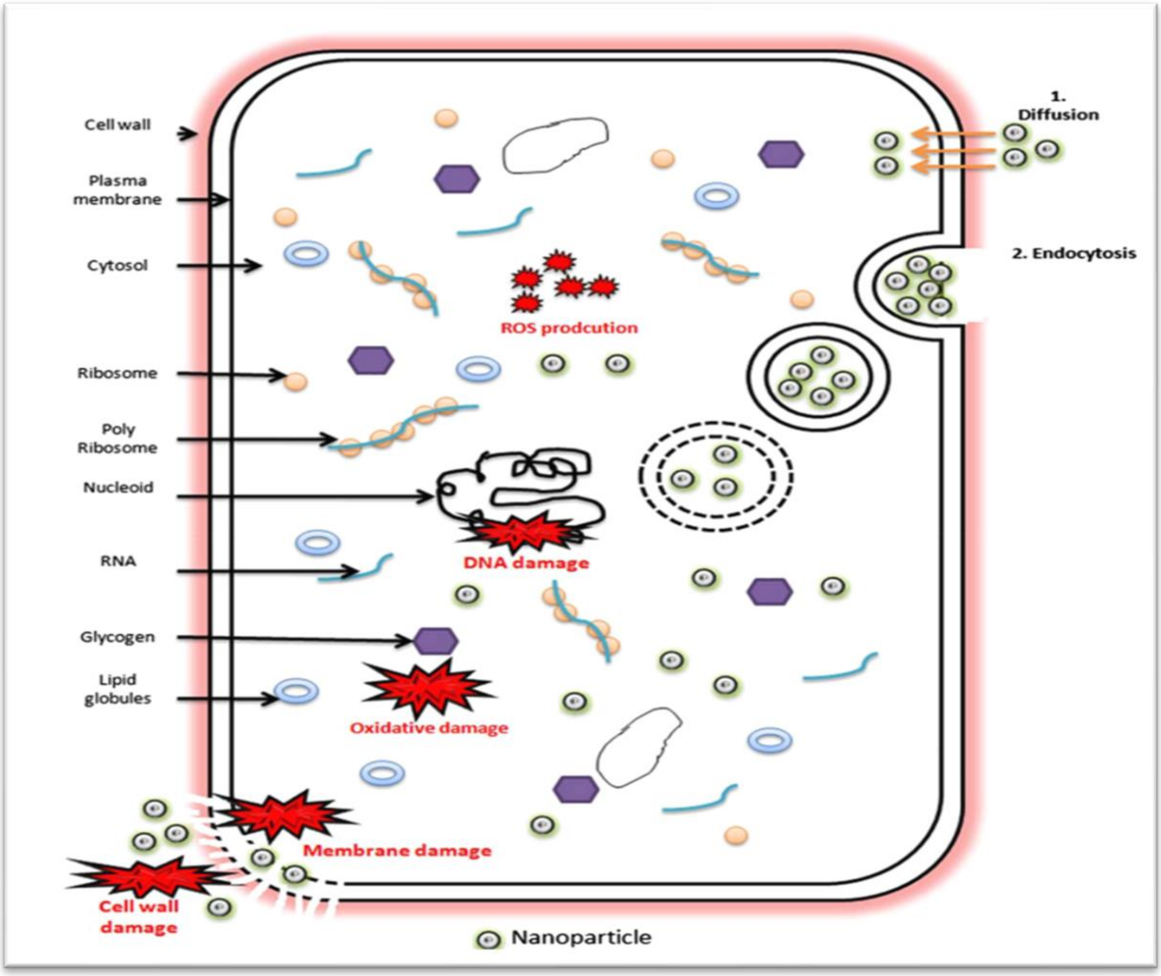

Fig 3: A schematic illustration of nanoparticle cellular absorption and the process of particle-induced toxicity against bacteria.

Conclusion and Discussion:

In conclusion, the schematic representation of cellular uptake of nanoparticles and the mechanism of particle-induced toxicity against bacteria can provide valuable insights into the interactions between nanoparticles and bacterial cells. The cellular uptake of nanoparticles involves complex processes that depend on various factors, including nanoparticle size, shape, surface properties, and bacterial cell characteristics.

Upon interaction with bacteria, nanoparticles can be taken up by cells through multiple mechanisms, such as passive diffusion, endocytosis, or specific receptor-mediated pathways. Once inside the cells, nanoparticles can interact with cellular components, leading to potential toxicity.

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