International Journal of Biological Innovations
http://ijbi.org.in | http://www.gesa.org.in/journals.php
https://doi.org/10.46505/IJBI.2022.4106
IJBI 4(1): 64-70 **(2022)**
E-ISSN: 2582-1032

APPLICATIONS OF NANOPARTICLES: A STEP TOWARDS A GREEN ENVIRONMENT

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Article Info:
Review Article
Received
15.01.2022
Reviewed
17.02.2022
Accepted
28.02.2022

Abstract: Nanotechnology has its wide applications in different fields of health, energy, electronics, environment, space exploration and transportation. Green means the use of plant products and green nanotechnology is the branch that utilizes the concept of green chemistry and green engineering. It reduces the use of energy and fuel by using renewable inputs and develops clean technologies in order to minimize health and environmental risks. These products, processes and applications save materials, energy and water thus contributing to the environment. Apart from the development of solar cells, biofuels and fuel cells, synthesis of nanoparticles using sunlight or by recycling the industrial waste to produce nanomaterials is also necessary. Thus, green nanotechnology encourages the substitution of existing products in order to develop new products. This article reviews the applications of nanoparticles with their green synthesis and emphasizes their use to make the environment clean and green.

Keywords: Environment, Green nanotechnology, Health, Nanotechnology.

Cite this article as: Jaiswal Shikha (2022). Applications of Nanoparticles: A step towards a Green Environment. *International Journal of Biological Innovations*. 4(1): 64-70. https://doi.org/10.46505/IJBI.2022.4106.

INTRODUCTION

There's plenty of room at the bottom (Feynman, 1960) means the feasibility of manipulation at nanoscale. Nanotechnology is a technology to study extremely small structures. It has various applications in fields of health, medicine, electronics, energy and environment. Nanotechnology deals with materials in size 0.1 to 100nm. At this size they display properties different from bulk materials like electric conductance, chemical reactivity, magnetism, optical effects and physical strength.

The Nano world is the intermediary between the atom and the solid, given in Table 1 from the large molecule or the small solid object to the strong relationship between surface and volume. Strictly speaking, the Nano world has existed for a long time and it is up to experts to study the structures and properties of molecules. They have learnt (with the help of physicists) to manipulate them and build more and more complex structures. Progress in observation tools such as electron microscopes, scanning-tunneling microscopes (STM) and atomic force microscopes (AFM) as well as in analysis tools (particularly X-ray diffraction (XRD), neutron and mass spectrometry) has been a decisive factor. The production of nanoscopic material is constantly improving, as is the case for the process of catalysis and surfaces used in the nano world. A substantial number of new materials with nano elements such as ceramics, glass, polymers and fibres are making their way onto the market and are present in all shapes and forms in everyday life, from washing machines to architecture. The milestones in the development of this field are tabulated in Table 2 and the initiatives taken for its periodical developments are given in Table 3.

Table 1: Comparative size of different things to understand the concept of Nano scale.

Things	**Water**	**Glucose**	**Antibody**	**Virus**	**Bacteria**	**Cancer cell**	**Tennis ball**
Nanometers (nm)	10^{-1}	1	10	10^{2}	10^{3}	10^{4}	10^{9}

Table 2: Milestones in the development in nanotechnology.

S.No.	**Scientist**	**Year**	**Development**
1.	Feynman	1959	Initiate the thought
2.	Taniguchi	1974	Coined the term Nanotechnology
3.	Binnig, Rohrer	1970s	Scanning Tunneling Microscope
4.	Binnig, Quate, Gerber	1980s	Atomic Force Microscope
5.	Harry Kroto	1990s	Bucky ball
6.	Iijima	1991	Carbon Nano tube
7.	Frietas	1999	Book on nanomedicine
	-----	2000	Launch of National Nanotechnology mission

On the basis of dimensions, nanomaterials can be classified as nanorods, nanowires with dimension less than 100 nm, quantum dots with dimension lesser than 100nm, and phase composition single phase (crystalline, amorphous and layers), matrix composites (coated particles) and multiphase system (colloids, aerogels and ferrofluids).

Table 3: Periodic developments in the field of Nanotechnology.

S. No.	**Year**	**Periodic development in the field of Nanotechnology**
1.	2001	Feynman Prize in Nanotechnology was awarded for development of nanometer scale electronic devices and synthesis of carbon nanotube and nanowires.
2.	2002	Feynman Prize in Nanotechnology was awarded for using DNA for new structures and advanced abilities to model molecular systems.
3.	2003	Feynman Prize in Nanotechnology was awarded for modelling the molecular and electronic structures of new materials and for integrating single molecule biological motors with nano-scale silicon devices.
4.	2004	Feynman Prize in Nanotechnology was awarded for designing stable protein structures and constructing novel enzyme. First policy conference on advanced nanotech held. First Nano-mechanical system was established.
5.	2005-10	3D Nano systems like robotics, 3D nanomaterials and change in their states during use.
2011-----Era of Molecular Nanotechnology started.		

Synthesis of nanoparticles

There are basically two general approaches for the synthesis of nanoparticles and the fabrication of nanostructures: Bottom-up approach and Top-down approach as shown in Fig. 1.

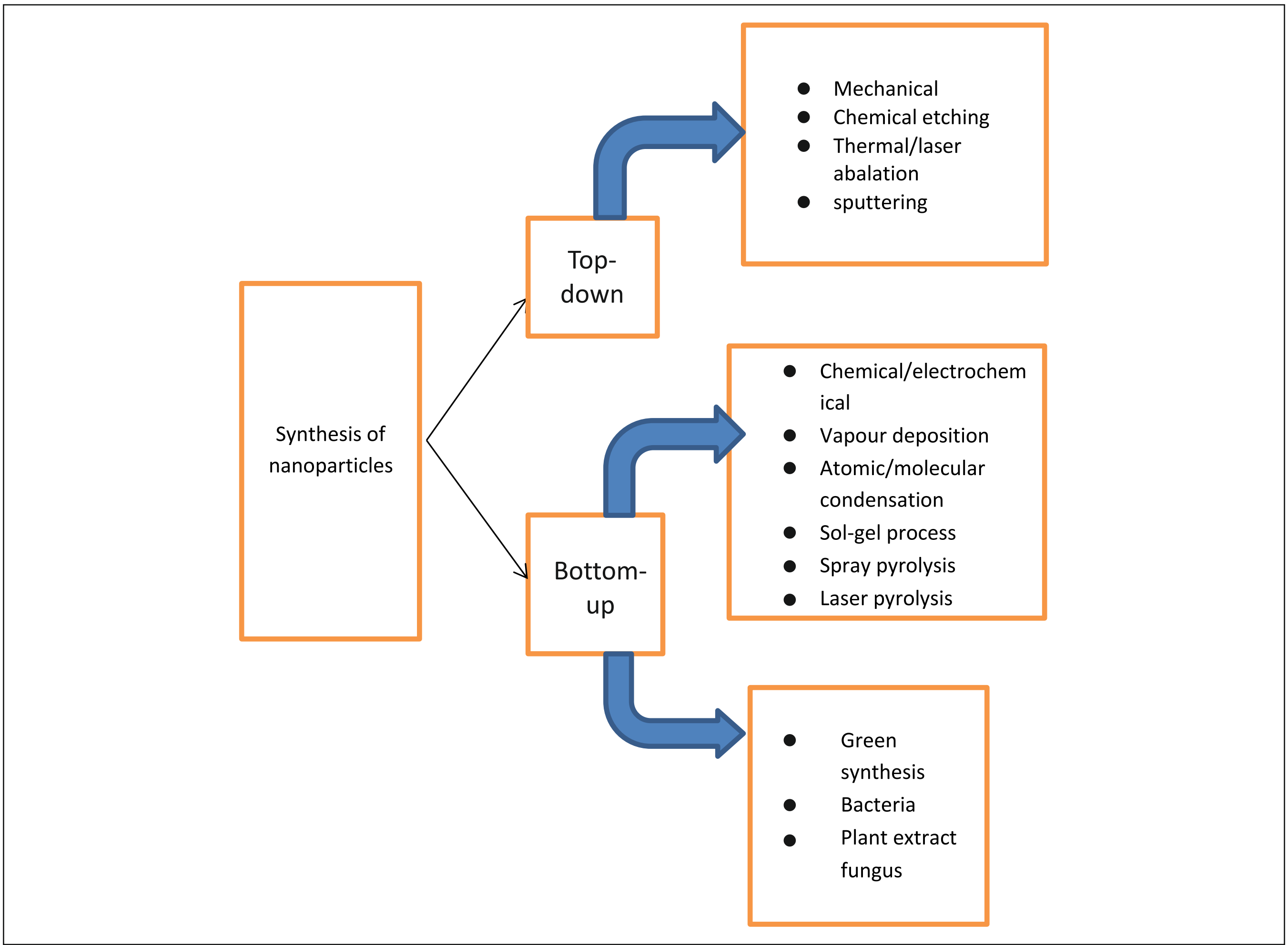

Fig. 1: Synthesis of nanoparticles.

1. Bottom-up Approach: It includes the miniaturization of material components (up to atomic level) with further self-assembly process leading to the formation of nanostructures. During self-assembly, the physical forces operating at nanoscale are used to combine basic units into larger stable structures. Typical examples are quantum dot formation during epitaxial growth and formation of nanoparticles from colloidal dispersion. Here, it is started with atoms or molecules and build up to nanostructures. Fabrication is also much less expensive.

2. Top-down Approach: It uses larger (macroscopic) initial structures, which can be externally controlled in the processing of nanostructures. Typical examples are etching through the mask, ball milling, and application of severe plastic deformation. Here, it is started with a pattern generated on a larger scale, then reduce them to nanoscale. By nature, they aren't cheap and quick to manufacture. It is slow process and is not suitable for large scale production.

In the recent years, there has been much concern about the synthesis of environment-friendly nanoparticles that do not produce toxic wastes in their process of synthesis (Mansoori *et al.*, 2007). This can only be achieved through benign synthesis processes of biological nature which are considered safe and ecologically sound for nanomaterial fabrication as an alternative to conventional physical and chemical methods (Joerger *et al.*, 2000) *i.e.* a step towards green technology using green synthesis.

APPLICATIONS OF NANOPARTICLES

Nanotechnology is revolutionizing almost all the major technology and industrial sectors namely information technology, medicine, homeland security, energy, environmental science and transportation, and many others. Nanoparticles are considered as the fundamental building blocks of nanotechnology (Mansoori, 2005; Mansoori *et al.*, 2007). The synthesis and characterization of nanoparticles and their applications represent a rapidly growing concept and an emerging trend in science and technology (Anstas and Warner, 1998; Li *et al.*, 2001). Nano particles have extensive use in targeted drug delivery. Titanium dioxide and zinc oxide nanoparticles are extensively used in sunscreen, cosmetics and some food products. Silver nanoparticles are used in food packaging, clothing, disinfectants and household appliances such as Silver Nano. Cerium oxide used as fuel catalyst. The nanotech solar cells and batteries using nanomaterials can be manufactured at significantly lower cost than conventional solar cells and batteries. The use of nanoparticles with their properties and applications are tabulated in Table 4.

Table 4: Applications of nanoparticles in different areas.

Nanoparticles	Properties improved	Industry
Aluminate, carbon nanotube, CNT, silicon dioxide, zinc oxide	Stiffness, durability, Light in weight	Polymer
CNT, silicon dioxide, titanium dioxide	Anti-reflective, self-cleaning electrically conductive, resistant to UV and infra-red	Electronics
Titanium dioxide, silicon dioxide	Cleansing, absorption, antioxidant, antimicrobial	Cosmetics
Silicon dioxide	Stronger and light weight	Sustainable energy
Titanium dioxide	Absorption, cleaner environment Environmental mediation	

Despite the advantages and applications with the bright future of nanotechnology, there is an increasing concern regarding significant health effects and environmental pollution. The field of Nanotoxicology is dealing with effects and risks of nanoparticles. A lot of more quality studies are required to assess the damage caused by nanoparticles. Transfer of nanoparticles through food chain is also a serious issue. The influence of nanoparticles on the environmental factors like humidity, temperature, and wind flow rate, nature of light is also significant. To maximize the benefits and minimizing the harm a step towards green nanotechnology is necessary though challenging but increases the energy efficiency, waste reduction, reduction in gas emissions and minimization of non-renewable raw materials (Maksimovi and Omanovi-Mikličanin, 2017).

SYNTHESIS OF NANOPARTICLES FROM PLANT EXTRACTS

In several studies, the biological routes to the synthesis of nanoparticles have been proposed by exploiting microorganisms and vascular plants (Anderson *et al.*, 1998; Nair and Pradeep, 2002; Ahmad *et al.*, 2003; Gardea-Torresdey *et al.*, 2003). However, the utilization of herbal and medicinal plant extracts for the synthesis of nanoparticles is a relatively recent activity. In a number of studies, gold and silver have been used mostly for the synthesis of stable dispersions of nanoparticles using the extracts of herbal and medicinal plants (Hussain *et al.*, 2003; Chandran *et al.*, 2006; Smith *et al.*, 2006; Kearns *et al.*, 2006; Armendariz *et al.*, 2009).

Plants extracts contain various bio actives such as alkaloids, proteins, phenolic acids, tepernoids and polyphenols which are used to reduce and stabilize metallic ions (Palak and Jain, 2018). Silver nanoparticles are said to inhibit the binding of virus to the host cell in vitro (Morones *et al.*, 2005; Elechiguerra *et al.*, 2005). Sulphur layer protein nanoparticles of *Bacillus sphaericus* have abilities to clean uranium contaminated waste water (Duran *et al.,* 2007). Magnetosome particles isolated from magnetotactic bacteria are used as a carrier for immobilization of bioactive substances such as enzymes, DNA, RNA and antibodies (Mohanpuria *et al.,* 2008). The gold nanoparticles synthesized by *E. coli* are used in electrochemistry of haemoglobin (Du *et al.*, 2007). To synthesize the paints embedded with nanoparticles, having antibacterial activity, vegetable oils are used (Kumar *et al.*, 2008). To enhance the properties of agrochemicals, nanoparticles are used (Sorensen *et al.*, 2003). The organic-inorganic nanohybrid materials for the controlled release of herbicides are also in process (Bin Hussein *et al.*, 2005; Liu *et al.*, 2006). The Nano emulsion non-toxic surfactant is also in process (Wang *et al.*, 2007). Different nanoparticles with the extracting plants and applications are tabulated in Table 5.

Table 5: Different nanoparticles extracted from the plants and their application.

Nanoparticles	Plants for extraction	Applications
Silver	*Aloevera, Rhododendron dauricum, Citrullus colocynthis*	Antibacterial, Drug delivery, Cancer treatment, biomarking, Coating for solar energy absorption
Gold	*Eucalyptus, Psidium guajava*, pear fruit extract	Catalysis, biosensing, antibacterial drugs, optics sensor, coating, hyperthermia therapy
Cadmium sulphide	*Annona muricata* leaf extract	Fluorescent labels
Zinc oxide	*Cassia fistula* and *Melia azedarach*	Catalysis, biosensing, drug delivery diagnostics
Titanium dioxide	*Psidium guajava, Eclipta prostrata* leaf	Antioxidant and antibacterial
Palladium	*Curcuma longa, Cinnamom bark* extract, custard apple peel extract, tea and coffee leaf extract	Catalytic material and application as hydrogen storage and sensing
Platinium	*Diopyros kaki*, Persimmon leaf extract	Biomedical applications like imaging, implants, photothermal therapy and drug delivery

GREEN SYNTHESIS OF METAL NANOPARTICLES

Green nanotechnology is a branch of green chemistry. The green synthesis moves the world from nanotechnology to green nanontechnology. The plants have good potential for biological reduction of metallic ions and hyper accumulation (Fig. 2), hence are more environmentally friendly. Using biological materials to produce nanoparticles is a bottom-up approach and can be used as a sustainable alternative to conventional nanoparticle synthesis.

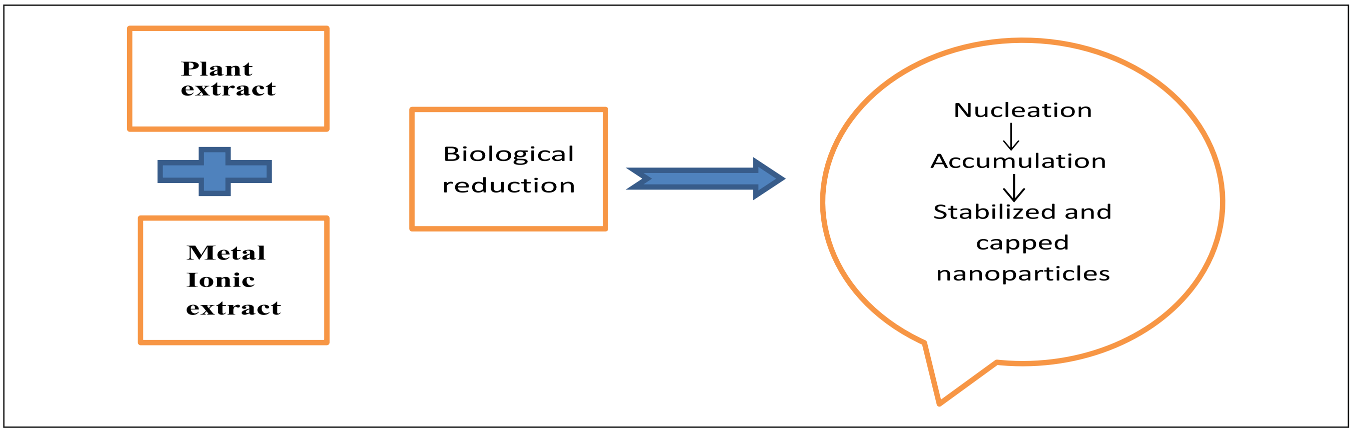

Fig. 2: Green Synthesis of nanoparticles.

The metallic salt solutions can be silver nitrate, palladium chloride etc. and the reducing agent can be amino acids, flavonoids, reducing sugar etc. After biological reduction, nucleation and production of nanoparticles starts, the capping agents to be used are enzymes, functional groups, proteins etc. and stabilized nanoparticles are produced.

The first step is to prepare the plant extract for the synthesis of nanoparticles and then metallic solution is mixed in plant extract for biological reduction. Once the bioreduction of metal to metallic nanoparticle by plant extract is done, the metallic nanoparticle is produced that can be analysed using UV (ultra violet) and Visible spectroscopy and characterization is done using SEM, TEM, XRD and is ready for applications.

CONCLUSION

The green nanotechnology has potential to become an eco-friendly industry with many advantages to step to go green but has challenges especially in research and development with high implementation cost and technical issues. This can take years to develop and productive but it will improve the quality of life, promotes environmental friendly commitments as well as ethical values.

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