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Role of biologically synthesised nanoparticles in environmental pollution remediation

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Environmental pollution is serious threat for all living organisms. Nanoparticle synthesis using green approach is a non-toxic, easy and energy saving process. Varieties of species have the unique capability to synthesize commercially useful nanoparticles from various metal salt precursors that can help in environmental remediation. The combination of nanotechnology and bioremediation is known as Nanobioremediation. Researchers have shown that biologically nanoparticles shows great potential in reducing environmental pollution from water and soil by adsorption of pollutants and harmful toxic substances from their environment .These greennanoparticles can converttoxic chemicals into less toxic form. Studies also shown that metal nanoparticles also help in removal of harmful bacteria and fungi from environment which can cause diseases in living system. Green synthesised nanoparticles shows very promising results when it comes to environmental remediation they have been used as dye degrader, Oil degrader, photocatalytic agents, biosensors, heavy metals and persidtent organic particulate (POPs) absorbers etc. This review focus on the current status of different types of biologically synthesised nanoparticles in environmental pollution from different species and future challenges associated with environmental remediation.

Keywords: Environmental pollution, Green synthesis, Metal nanoparticles, Nanobioremediation

Introduction

Environmental pollution is one of the major concern in today's world. With increasing population and growing demands of humans we are deteriorating our environment which further leads to environmental calamities causing huge loss of lives, biodiversity and money. It takes a huge amount of time for removal of pollutants from air, water, soil. Industries are one of the main contributor of environmental population. Today, world is in an age of emergency because of tremendous damage done to environment[1]. So, to combat such a large challenge we need a sustainable approach which is environment friendly as well as effective in achieving the goal of pollution free environment.

Nanotechnology is proved to be a major key player over a period of time in developing a cleaner, much effective way to combat environmental issues. Nanoparticles because of their high surface to size ratio are very effective in performing their functions[2]. Nanoparticles uses variety of mechanism to reduce environmental pollution such as absorption, adsorption, catalysis reactions, filtering *etc*[2]. Nanotechnology has a great potential of replacing conventional energy consuming methods used to get rid of environmental pollution. Till date they have been shown to be effective from a small scale problem to large scale pollution issues such as oil spills, removing hazardous chemicals from groundwater *etc*.

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Approaches for synthesising nanoparticles

Nanotechnology, deals with the studying and understanding the materials in the nanoscale generally size of 1-100 nm. The two main strategies for the synthesis of nanoparticle includes The "*Top-down approach"* and the *"Bottom-up approach"*[1] (Fig. 1). The top-down approach includes the synthesis of nanoparticles by physical means in which bulk materials are fragmented into smaller fine particles by reducing their size it includes techniques like sputtering, grinding, milling, *etc*. The bottom-up approach includes nanoparticle synthesis by chemical and biological methods, in this approach nanoparticles are synthesized by the self-assembly of atoms, nanoparticles are synthesized chemically by chemical reduction, electrochemical methods, and sonode composition. Biologically nanoparticles are synthesized by using bacteria, fungi, plant extract[1], *etc*.

Biological synthesis is one of the approaches that become very popular over a very short period of time.

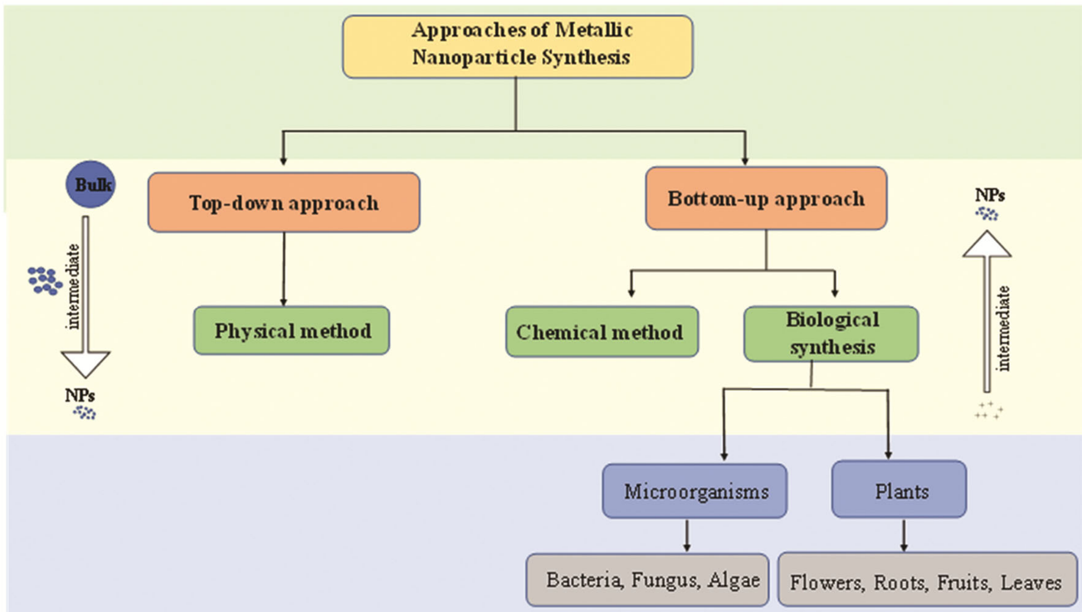

Fig. 1 — Approaches for nanoparticle synthesis

It uses biological system for the nanoparticle synthesis. Various species of plants, fungus, bacteria, algae *etc*. have been used for biological synthesis of nanoparticles. The biological synthesis of nanoparticle is also called green synthesis, have several advantages over other processes of nanoparticle synthesis.

- Green synthesis is a non-toxic approach to nanoparticle synthesis as it does not require any toxic chemicals unlike physical and chemical methods and does not cause environmental stress and hazardous impact on human health[2].
- It is a relatively simple process, which can be scaled up easily.
- Nanoparticles produced by green synthesis are highly stable and are very well characterized.
- It is an energy-saving process as external experimental conditions are not required like high temperature, high energy, and pressure[2].
- Biological systems are capable of reducing and capping the nanoparticle by themselves, therefore, requiring less cost.

Mechanism of biological nanoparticle synthesis

Microorganisms and plant extract contain large number of biomolecules (protein, nucleic acids, carbohydrate, lipids) that are highly secretory in nature and helps in metal nanoparticles reduction when exposed to different metal salts. These biological entities are directly involved in the bio-reduction as well stabilization in process of nanoparticles synthesis. Living system contains different type of metal reducing enzymes namely NADH dependent nitrate reductase, Fe dehydrogenase[2]. These biomolecules have different physiological function such as heavy metal detoxification, environmental stress rescue and resistance, bidirectional transport of metal and drug/chemical molecules[3]. Many species have been used as a potential nanofactories for the synthesis of different metal nanoparticles like Zn, Au, Ag, Fe, Mn, Pd, Cu, Ti and Pt, *etc*[3].

Metal nanoparticles in microbes are synthesized *via* two approaches: extracellular approach and intracellular approaches[4] (Fig. 2). In extracellular approaches metal ions are reduced on the surface by binding biomolecules or by enzymes secreted by microbes outside the cell surface whereas in intracellular approaches metal ions are transported inside the cell and nanoparticles are synthesized by intracellular enzymes in cytoplasm or inside various organelles. Nanoparticles obtained from these biological systems have been shown to have the property of monodispersity, well-defined shape, uniform and homogenous in nature with wide range of functional group present.

The heavy metals are generally poisonous; microbes have evolved specific resistance mechanisms and metabolic pathways to get rid of these metal ions. These detoxification events lead to formation of nanostructures that can be utilized for many commercial, clinical, industrial, environmental applications. Some of the processes that can convert metal ions into

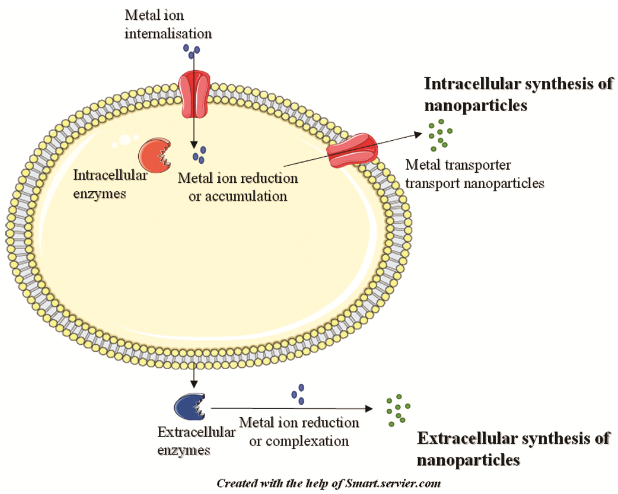

Fig. 2 — Extracellular and Intracellular synthesis of nanoparticles

nanostructures are Bioleaching, Bioaccumulation, Biotransformation, Biosurfactantand Biosorption[3].

Bioleaching

Bioleaching, also known as microbial leaching, is a method of enhancing the solubilization of solid phase heavy metals by using acidophilic microbes. Bioleaching mostly targets heavy metal components in sediments associated with iron minerals, *e.g.*, *Aspergillus niger* can bioleach various metals from contaminated sediments[3].

Bioaccumulation

In the process of bioaccumulation microbes actively transport metal ions inside the cells and various cellular organelles by passive channels, ion pumps and carrier mediated transport. *Pseudomonas aeruginosa* and *Saccharomyces cerevisiae* have been reported to actively transport Ag ions inside cytosol[3].

Biotransformation

Microorganisms can interact with heavy metals and involve in their biotransformation through methylation, demethylation, oxidation, reduction, or complexation, by different metabolic activities. By changing the speciation of metal ions in their immediate environment also changes their physiological properties like solubility, mobility as well as toxicity. *Geobacter sulphur reducens* have been proved for removing Cr(VI) by converting it into Cr(III) from sediments[3].

Biosurfactant

Biosurfactant are active amphiphilic compounds present on the surface of the cell walls. They can form special complex system with the metal ions and involve in nanoparticle synthesis. *Pseudomonas* species have been proved to effective in reducing Cd, Cu and Pb by using glycolipid biosurfactant[3].

Biosorption

Cells are accompanied by various types of surface molecules and entities. These interaction can be physical as well as chemical .Various ionic and covalent changes occur on heavy metal ion during these interactions. There are various anionic molecules, polysaccharides, proteins present on the surface of these cells which can help in biosorption and reduction of heavy metal ions into nanostructures. *Shewanella putrefaciens* have been proved to be involved in the biosorption of Cd ions[2].

Biologically synthesised nanoparticles for soil remediation

With increasing industrialisation the soil become highly polluted with toxic chemicals, dyes, metals. Since plants depend on soil for their growth, these toxic chemicals can enter into food chain and cause biomagnification in subsequent tropic level. Further humans are totally dependent on soil for in food needs, and these toxic chemicals can make land infertile or barren which is incapable of growing anything [8]. Today heavy metals and Persistent organic pollutants (POPs) are biggest threat to environment[2]. Nanoparticles shows highly effective role in getting rid of these substances.

Iron nanoparticle synthesised by *Vaccinium floribundum* acts as a reducing as well as stabilising agent. They have proved to removing total petroleum hydrocarbons (TPHs) material from soil and water samples. These iron nanoparticles were found to be 88.34% effective in removing these pollutants[5].

Helicteres isora synthesised AgNPs are highly effective in degrading a wide varities of organic dyes[6]. Au nanoparticles produced by bacteria Shewanella putrefaciens have been shown in involving biosorption of Cd nanoparticles[2].

Biologically synthesised nanoparticles are also utilised in as biosensors for monitoring of the heavy metal pollution[7].Nanobiosensor is a device in which biological unit is attached to the transducer in the scale of nanometer. Recently, the detection of heavy metals in water and soil has been carried out using a range of nanomaterials (antibodies, nanoclusters, aptamers), and nanodevices (quantum dots, cantilever biosensors and FRET)[7]. Arsenic is one of the major soil pollutant. Utilizing integrated nanobionic sensors to measure the plant Pteriscretica natural capacity to accumulate arsenic. The nanobionic sensor can identify changes occurring in real time inside the plant as a result of the heavy metal absorption[7]. According to the study, after two weeks, nanobionic sensors could detect arsenic levels ranging from 0.6 to 0.2 ppb[7].

Biologically synthesised nanoparticle in remediation of water pollution

Commercial industries, wastewater discharge, untreated domestic sewage, and synthetic toxins into aquatic system degrade the ecosystem as well as human health. The main sources of water pollution in this respect are heavy metals, organic compounds, and oils, which can make any water stream unsafe for ingestion[2]. The development of nanotechnology has led to the emergence of a wide range of innovative nanomaterial-based technologies. Nanoparticles have been proved more effective than activating carbon as a absorbent system of toxic chemicals. 4-Nitrophenol is one of the derivative of varieties of insecticides, pesticides *etc*. It is highly toxic and reaches wastewater[9]. It is one of the major environmental concern to get rid of these. The introduction of NaBH4 as a reductant and a metal catalyst, such as Au, Ag,CuO and Pd NPs, is the quickest and most efficient technique to reduce 4-nitrophenol[9].

AgNPs synthesised from *Citrus sinensis* peel extract (Orange peel extract) can degrade azo dye and congo red dye used in textile industries very effectively[10]. Silver nanoparticles made from *Z. armatum* leaf extract show improved photocatalytic degradation of several pollution dyes[11].

Polluted water is also a main source of various pathogenic bacteria, fungus, protozoan's, *etc*. These pathogenic organisms are great threat for public health and cause various water borne diseases like cholera, Diarrhea, typhoid, amoebiasis, *etc*. further these microbes develop drug resistance over a period of time which makes them lethal. Biologically synthesied nanoparticles show antibacterial, antifungal as well as antiparasitic activity[12]. The Antimicrobial activity of nanoparticle depends on the size of the nanoparticle as well as material employed during the synthesis of nanostructures. Zinc oxide (ZnO), copper oxide (CuO), and iron oxide (Fe2O3) nanoparticles were tested for their ability to kill both gram-negative (*Escherichia coli* and *Pseudomonas aeruginosa*) and gram-positive bacteria (*Staphylococcus aureus* and *Bacillus subtilis*) by Azam *et al*. When compared to chemically produced and, green synthesised nanoparticles Green nanoparticles have improved antibacterial activity [13].

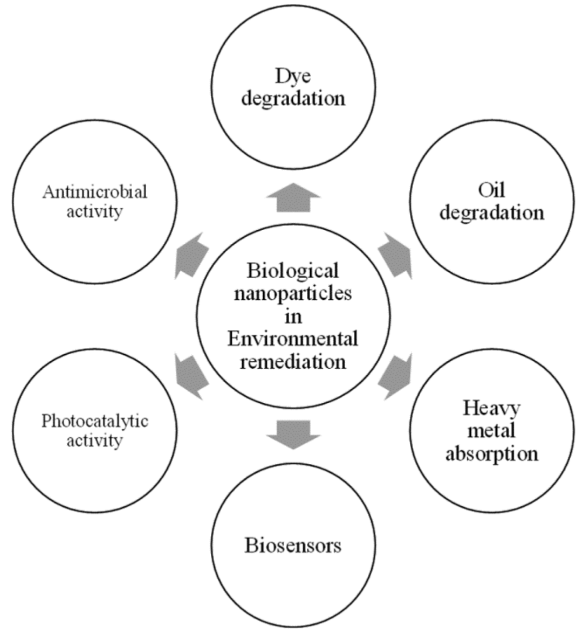

Fig. 3 — Applications of biological nanoparticles in environmental remediation

This is because the Organism used in the manufacturing of nanoparticles– like *Ocimum sanctum* and *Azadirachta indica*– have therapeutic characteristics[13]. For instance, compared to chemically synthesised silver nanoparticles, green synthesised silver nanoparticles demonstrated an effective and larger zone of clearance against several bacterial strains[5].

Biologically synthesised nanoparticle in remediation of air pollution

Biologically synthesised nanoparticles can aid in air purification. One approach is to utilise nanocatalysts with a larger surface area for gaseous reactions. Catalysts quicken chemical reactions that turn dangerous fumes from vehicles and factories into harmless gases[1].

Cerium oxide nanoparticles produced by plant extract of *Jatropa curcus* have shown to reduce indoor pollution significantly. CeO_2 NPs have been proved as photocatalytic degrader of gaseous pollutant acetaldehyde and further found to be more effective than the chemically synthesised nanoparticles[14].

The summary of applications of biological nanoparticle synthesis in environmental remediation are given in (Fig. 3).

Conclusion

Green synthesis of nanoparticles are very effective tool in synthesising nanoparticles with the minimal use of chemicals. The environmental remediations of green nanoparticles have vast possibilities. Bacterial, Fungal, algal and plant extract from wide varieties of species are employed for getting suitable nanoparticles. These nanoparticles are used in soil, water and air pollution. These nanoparticles shows properties of dye degration, heavy metal absortion, Organic matter absorption, photocatalysis, filtering, *etc*.

The environmental damage done by humans over a period of time need a large scale solution. There is vast unexplored possibilities in the area of green synthesis for environmental remediation. Most of the research that have been done till date are in small laboratories condition, these effective NPs needs to be transformed and synthesised into large industrial scale. Further, the vast majority of species that can be employed for biological nanoparticle syntheses for reducing environmental pollution are unexplored like marine algae.

Other key challenges in biological nanoparticle synthesis are – Suitable capping agent which can enhance property of environmental remediation, managing the size of nanoparticles, nanoparticles free of organic components. These problems are further need research to obtain a ideal solution.

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Conflict of interest

The author declares no conflict of interest.

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