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Biological Synthesis of Metallic Nanoparticles and their Applications

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Abstract: Nanoparticles have a wide range of applications in our day to day life. Different methods of biological synthesis of metallic nanoparticles are being employed worldwide and many researches are still underway as a part of improvement strategy. Various microorganisms and abundant plant materials are used for this purpose. A chemical reducing agent is often replaced by the extracts of plants and microorganisms during the biosynthesis phenomena of nanoparticles which have proven to be novel approach in recent years. Biosynthesis of some important metallic nanoparticles and their applications is the main objective of the study.
Keywords: Nanoparticles, Biosynthesis, Reducing agent, Plants, Microorganisms and Metallic Nanoparticles

I. INTRODUCTION

Nanoparticles are minute particles that can be used to deliver a specific compound or can also inhibit the effect of particular responses in a defined target system in terms of Biotechnology. They are smaller in size usually ranging from 1 to 100 nm. Lipid-based, metallic, inorganic and polymeric nanoparticles are the major types(Ahmed, 2020). Biologically, nanoparticles can be synthesized using bacteria, fungi, plants etc., which has wide applications such as in medicine, agriculture, pollution reduction and even cosmetics(J. Singh et al., 2018).

Nanoparticles may be singly present or in the combined forms like sulphides or oxides. Recently, Nanobiotechnology focuses on microbes or plant based green synthesis of some major metallic nanoparticles like Ag, Au, Cu, Fe, Pd, Ru, PbS, CdS, CuO, CeO2, Fe3O4, TiO2, and ZnO and their potential applications in the above mentioned fields. Heavy metal nanoparticles may induce mutations in DNA, transcriptome and proteins and hence can be used to cure cancer and viral infections. In this study, most of the nanoparticles are synthesized by adding an aqueous solution of the metallic compounds with a definite amount of plant extract which will potentially reduce the compounds and finally form metallic nanoparticles having unique properties and nature. Capping and stabilizing agents present in biological extracts act as growth terminator and inhibits agglomeration processes enhancing the stability and persistence of nanoparticles. Metallic Nanoparticles contribute to drug delivery, chemical sensing, food, agriculture, textiles, data storage and antioxidants agents. Despite having toxic properties with other metallic oxides, it strongly acts as antimicrobial and disinfectant agents and improves the green synthesis by enhancing the reactions. Green synthesis is a process where the production of sustainable and eco-friendly procedure is followed to remove the unwanted substances. Biogenic nanoparticles is the synthesis of metal or metal oxide nanoparticles by utilizing plant extracts which can be used to produce NPs at large scale relative to bacteria or fungi mediated synthesis.

II. POLYMERIC NANOPARTICLES

Polymeric nanoparticles are generally larger than other types of nanoparticles. The main advantage of polymeric nanoparticles is that they are non-immunogenic and does not allow the body to produce antibodies against them. They are water soluble and non-toxic. Polyethylenimine and polylysine are such polymeric nanoparticles that help in the delivery of large samples into the target system. Dendrimers are polymeric NPs which contain internal cavities, surface functional groups and a core moiety at the centre. Polymer micelles consist of amphiphilic block copolymer having both hydrophilic and hydrophobic structures making it easy to deliver via a transport medium. Polymersomes are similar to that of polymer micelles which especially carry hydrophilic drug molecules. The target drug is surrounded by a spherical polymer matrix in nanospheres.

III. LIPID-BASED NANOPARTICLES

Lipid-based nanoparticles find application in the ease of delivery of molecules at the cellular level within the body. Liposomes resemble the structure of cell vesicles containing phospholipid-bilayer membrane. Both lipophilic and hydrophilic moieties can be delivered simultaneously. Emulsion NPs are made up of an oil core and surfactant within which target molecules are present. Nano-structured lipid carriers contain both solid and liquid lipids in its structure.

IV. INORGANIC AND METALLIC NANOPARTICLES

Silica nanoparticles have mesoporous silica structures in which the target compounds are found. Other than this, carbon nanotubes are linear tube-like structures that also aid in the delivery of drug into the body. In metallic nanoparticles, the target molecules which have to be delivered are found to be attached onto the surface of the nanoparticles whereas in other NPs the target compound are either embedded or filled within the cavity of the NPs. These nanoparticles are normally made up of a few hundred atoms of metallic elements.

V. BIOLOGICAL SYNTHESIS OF NANOPARTICLES

The advancement of organisms has paved way to endure in environment of high concentration of metals. These organisms may either alter the chemical nature of toxic metals by lowering their toxicity or making them completely non-toxic(P. Singh et al., 2016).The nature of biological entities in different concentrations with combination of organic reducing agents influences the size and shape of NPs. At this point, we investigate and feature the expected employments of diverse organic hotspots for nanoparticles unify and the exploitation of those nanoparticles.

In addition, we facet enduring achievements accomplished for the biogenic combination of nanoparticles by controlling basic boundaries, counting the decision of natural source, pH, and temperature(Ingale & Chaudhari, 2013). Nanoparticles can be synthesized biologically by means of biocompatible methods without causing adverse effects on the environment. Microorganisms like *Fusarium oxysporum, Thermospora sp., Verticullum sp., Rhodococcus sp.,* and *Lactobacillus* can be used for the synthesis of gold nanoparticles in different shapes and dimensions giving unique property to each of the nanoparticles. *Staphylococcus aureus, Fusarium oxysporum, Pseudomonas stutzeri* and *Aspergillus flavus* can be used for the silver nanoparticles production both in-vivo and in-vitro conditions. Silver nanoparticles have antimicrobial properties and hence can be used as antibiotic medications and recently silver nanoparticles coated hand sanitizers. Yeast cells and *Fusarium semitectum* are helpful for the synthesis of other alloy nanoparticles. *Magnetospirillum magnetotactium* and *Magnetospirillum magneticum* can be used for magnetic nanoparticles synthesis. These magnetic nanoparticles aid in the isolation and purification of proteins, DNA and RNA for molecular biology and rDNA technology experiments.

VI. IRON NANOPARTICLES

Fe nanoparticles play a significant role in pollution reduction. Fe nanoparticles can be synthesized by biocompatible reagents such as sodium alginate and starch. Sodium alginate and starch being comparatively inert biopolymers, can be used to produce morphologically uniform and stable Fe NPs(Saif et al., 2016). *Thiobacillus* are commonly used iron reducing bacteria which can be used in the synthesis of iron nanoparticles. *Sargassum muticum* is a macroalgae that can reduce ferric chloride to form iron nanoparticles.

Iron nanoparticles can be synthesized from papaya leaf extract and *Camellia sinensis* proving it to be a significant and simple method of production(Bhuiyan et al., 2020)(Herlekar et al., 2014).

VII. SILVER NANOPARTICLES

Silver nanoparticles are good at killing bacteria and cells. These are made by mixing silver nitrate and Aspergillus oryzae and Aspergilus fumigates fungi.

Ag NPs are used mainly in biomedical applications as antimicrobial agents, biomedical device coating, drug-delivery and for cancer diagnosis(Zhang et al., 2016).

It is used in medical, health care fields due to its unique chemical and physical properties such as thermal conductivity, optical, biological properties and so on. Silver NPs suppress cell growth, multiplication and eventually leads to cell death due to over concentration and duration of silver exposure on the cells.(Norwegian Institute of Public Health, 2012)

VIII.PALLADIUM NANOPARTICLES

Fruit extracts of *Terminalia bellirica* and *Catharanthus roseus* have been most widely used in the synthesis of Pd nanoparticles as of now. Palladium nanoparticles can be synthesized by mixing an aqueous solution of palladium compounds with methanolic plant extracts at 60̊ C(Viswadevarayalu et al., 2016). The presence of polyphenols in these plant species can potentially reduce the metallic compounds of palladium to produce palladium nanoparticles(Siddiqi & Husen, 2016)(Ascanio, 2015).

IX. COPPER NANOPARTICLES

Cu nanoparticles are less expensive to produce and require less maintenance too. Plant leaf extract of Magnolia can be used with which aqueous solution of copper sulphate was added. Here, the compounds present in Magnolia reduce copper sulphate to form copper nanoparticles(Lee et al., 2011). *Streptomyces spp.* can also be used to prepare copper nanomaterials at low expenses.(Bukhari et al., 2021)

X. ZINC NANOPARTICLES

Zinc nanoparticles can be used as antimicrobial agents, removal of dye, antioxidant, pollutant controller, and in the synthesis of pyrazolines. Various bacterial species such as *Bacillus licheniformis, Aeromonas hydrophila, Lactobacillus johnsonii, Pseudomonas aeruginosa,* and *Staphylococcus aureus* can be used. Fungi like *Aspergillus niger, Aspergillus fumigatus, Candida albicans, Pichia fermentas* and *Fussarium spp.,* can be used. These microbial cells are suspended in aqueous solution of zinc or the supernatant of culture broth can be added to the zinc precursors for Zn NPs synthesis(Mohd Yusof et al., 2019).

XI. GOLD NANOPARTICLES

The majority of greener synthetic efforts reported earlier are dedicated to Ag and Au NPs, which may be due to their importance in disinfection science. Pure gold nanoparticles are synthesized in a bacterium called *Delftia acidovorans*. These bacteria contain small non-ribosomal peptides and are considered liable for synthesis of gold nanoparticles as it is known to induce resistance against toxic gold ions. The bacteria synthesize inert gold nanoparticles and hence do not show toxicity to the organisms.

XII. CHARACTERIZATION

The structural characteristics are primarily important to study the composition nature of the nanoparticles. The common techniques to study the properties are XRD, IR and BT. Biologically synthesized nanoparticles are characterized with the help of UV- Vis spectroscopy, TEM, SEM, AFM, DLS and FTIR. NP's were examined in the AFM operating in air under ambient conditions. The size and shape of the NP's are characterized using TEM at 120Kv and at 360-2000 nm in UV-Vis spectroscopy(Tomaszewska et al., 2013). The nanoparticles were allowed to run on HPTLC and was sprayed with luminol and hydrogen peroxide which was then examined for chemiluminescence(Yan et al., 2016)(Preetha et al., 2013).

XIII.APPLICATIONS

Nanoparticles have wide range of applications in biotechnology field like medicine, agriculture, pollution control, cosmetics and research. Metallic nanoparticles are mainly used as antimicrobial agents against viruses, bacteria, fungi and can also cure cancer by inducing mutations in tumour cells or exactly in the oncogenes. Polymeric, lipid-based and inorganic nanoparticles aid in the delivery of target compounds such as drug molecules into the body. Some nanoparticles especially gold is coupled with antibodies so that they can be used in diagnostics. Silver nanoparticles can be used as an active ingredient in alcohol-based hand sanitizers which can significantly kill microorganisms. Many of the metal nanoparticles coated onto heavy material will reduce the effect of radiations.

A. Applications In Drugs And Medicines

Nanoparticles having small, complex structure show unique chemical and physical properties. They have a wide range of use in biomedical and pharmaceutical applications. Metallic NPs are potential for SPR (Surface Plasmon Resonance) and cancer diagnosis(Khan et al., 2019). Nanoparticles are used in the medicine field as it has the ability to deliver drugs to the specified target site in a specific required range while minimizing the side effects. With the optical properties of NPs, photo thermal therapeutic applications such as cell imaging is also been used in the biomedical field. Hydrophilic NPs as drug carriers has been represented in the last few years, of which polyethylene oxide and polylactic acid are used in intravenous administration of drugs.

Super paramagnetic iron oxide NPs with its numerous properties can be used in MRI(Magnetic Resonance Imaging), MPI (Magnetic Particle Imaging), MFH (Magnetic Fluid Hyperthermia) contrast enhancement, tissue repair, immunoassay and cell separation(Dadfar et al., 2020). Smaller size, high magnetization value makes it an important factor for which NPs are in the biomedical field for diagnosis and treatment (Dung et al., 2021)t. Au NPs convert absorbed light to localized heat for photo thermal of cancer. Ag NPs possess antimicrobial activity and is used in wound dressings and catheters. Metallic NPs like Ag, Ni, Zn, etc., are reactive with proteins and affect the transportation system across the plasma membrane and leads to the death of bacteria due to its magnetic mirror and toxicity nature. TiO2 NPs are used in drug delivery and even in gene delivery. Fe NPs are most probably used in Bio-imaging, biosensors and Hyperthermia.

B. Applications in Electronic and Mechanical Industries

NPs are used in the manufacturing of materials as it has high optical properties, magnetic properties and improved mechanical activities. Nanomaterials are used in industries as it has increase relative surface area and new quantum effects which helps in binding and building materials with its high ductility properties(Subhan et al., 2021). Ni NPs act as electro-catalysts, photo-catalysts, biosensors and heat changers in many chemical reduction, photo-catalytic reduction and discharging processes(Ahghari et al., 2020)(Okoli & Briggs, 2013). Mostly, Carbon NPs are used because of the carbon structure and its chemical properties, it has high wear resistance, light weight and break strength. Aerospace materials are made using NPs as it is light and stronger, by reducing the weight, consumption of fuel is lowered and is economically feasible. NPs in coating materials are used because of its properties and size it can prevent corrosion and regulate the systems from mechanical and chemical damage. Ag NPs through its electrostatic stabilization can decrease the agglomeration, which increases its stability in the coating techniques.

C. Applications In Energy And Environment Conservation

NPs are eco-friendly as it of wide range of metal and its oxide, it is extracted in a natural manner by reducing the total emission concentration of extracting other materials(Bundschuh et al., 2018). NPs being more stable, highly efficient and low cost are used for catalysis and Solar Energy Conservation and other energy conversions. NPs are used in controlling pollutions, water treatment, natural-renewable energy resources which are cost-effective. With the help of NPs light absorbance level, the efficiency of energy is increased by using nanostructures with a continuum band gap. Using NPs as soil fertilizers will reduce the chemical content, maintain soil health and increase the yield efficiently(Derosa et al., 2010). Carbon and TiO2 NPs in solar panels will absorb the light in an effective way. Carbon Wind blades in Windmill are light weight and can generate even more electricity efficiently. Metal NPs are used in the removal of pollutants, dyes that can enhance catalytic, antimicrobial activities and heavy metal ion sensing, etc.,

XIV. DISCUSSION

The metabolites of plants and microorganisms themselves act as reducing agents that react on the metallic compounds to yield nanoparticles of desired size and shape. Some of the chemical compounds used in the production of nanoparticles show toxic effects and the NPs have relatively low shelf life period and hence they are replaced by bio-compounds. The biological methods are environmental friendly and less expensive which brings out the main advantages of switching over from artificial synthesis to biosynthesis of nanoparticles.

XV. CONCLUSION

Metallic nanoparticles can be efficiently synthesised by biological methods using microorganisms and plant extracts. They can be used as drug delivery molecules, antimicrobial, anti proliferative agents and semiconducting materials etc., Biological compounds tend to show excellent reducing properties and have promising results in the synthesis of metallic nanoparticles. A wide variety of nanoparticles are being explored in various fields such as industries, agriculture and Biotechnology. Metallic nanoparticles produced by means of chemical reduction using biological materials are found to be more stable. Therefore, Biosynthesis of nanoparticles is cost-effective, non-toxic and eco-friendly technique that can bring forth revolution in the scientific community.

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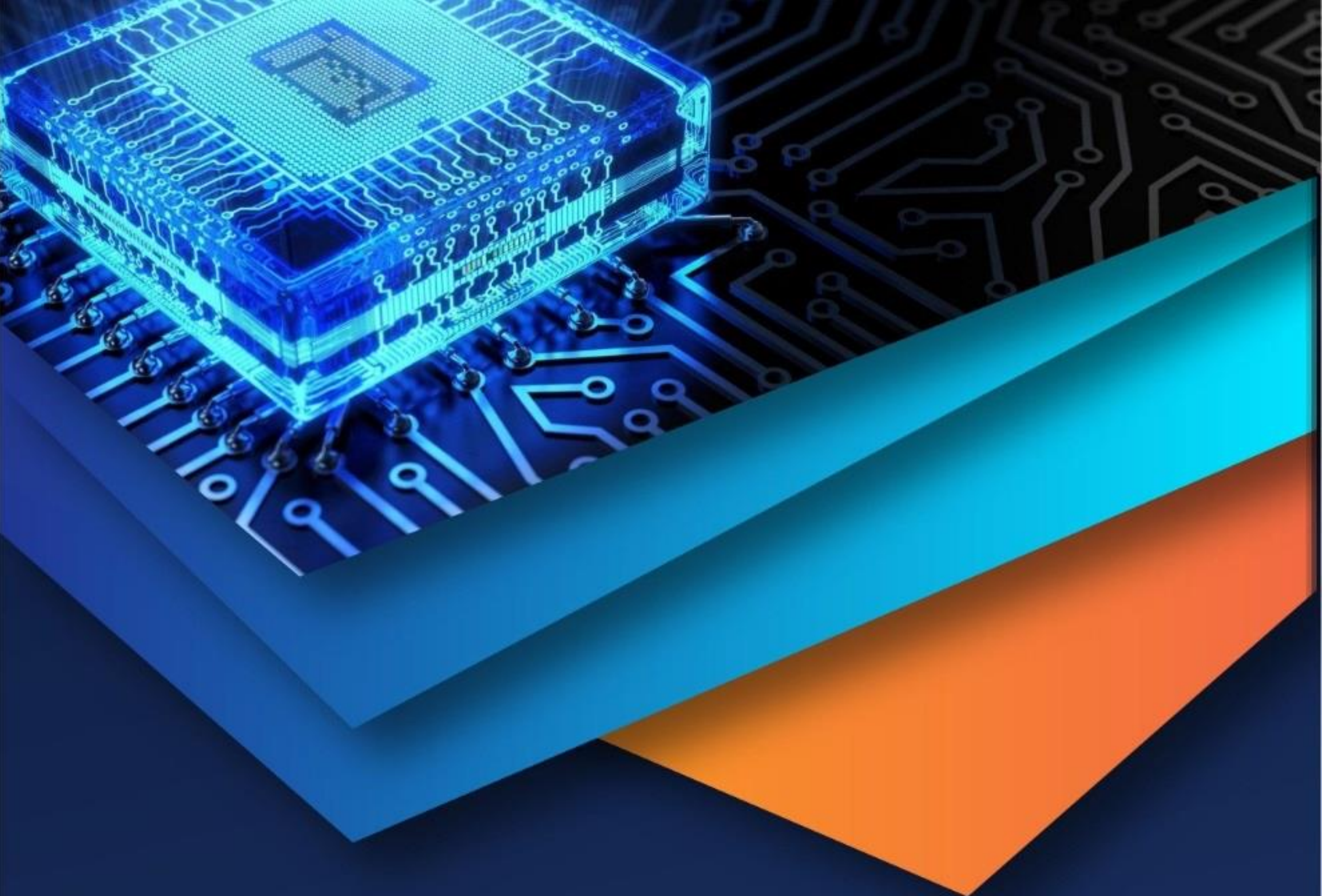

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