Review on Synthesis of Nanoparticles by Different approaches and from biological sources

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Abstract

The uprising in materials science has been hosted by before many decades. There has been a significant research interest in the area of using particulate systems to accomplish diverse approaches. The synthesis of material with nanoscale accuracy by means of material science is nanotechnology. Nanoparticles are solid particles, with a size in the range of 1-100 nm. This review intends to present Synthesis of nanoparticles by different approaches also from biological sources here, we discussed different synthesis methods, chemical, physical and biogenic synthesis of nanoparticles. The potential come together between nanotechnology and biological science is enormous. Plants play a key role in the green synthesis of nanoparticles by providing a readily available, eco-friendly, and cost-effective source of reducing and stabilizing agents. Plant extracts, containing various phytochemicals can reduce metal ions into nanoparticles and help maintain their stability. biological method offers a safer and more sustainable alternative to traditional chemical and physical methods for nanoparticle synthesis.

Keywords: Nanoparticles, Physical methods, Biological and Biosynthesis.

Introduction

Nanotechnology is an interdisciplinary area of science which has been burgeoning interest across the globe with huge momentum to usher in forming nano revolution. An important area in nanotechnology deals with the synthesis of nanoparticles which has encountered immense progress due to innumerable applications in recent decades (Cheon *et al.*, 2009). The recent development and implementation of advance technologies have emerged the nano-revolution which provides the tools and technology as platforms for the investigation of biological entities which offer inspiration models for bio-assembled components toward synthesis of nanoparticles. Nanotechnology has now started leaving the confines of laboratories; and conquering new applications to change our lives. Cutting edge research in nanotechnology has seen the combination of the fields of physics, chemistry, engineering and biology leading to the development and refinement of technology to fabricate and examine materials in the nanoworld (Grzelczak *et al.,* 2008). Industrial revolution in the twentieth century has led to the accumulation of huge quantities of harmful industrial wastes resulting in numerous health problems. Since its advent, nanotechnology has been showing potential in many improbable areas creating them implemental in the form of Nanoparticles.

Synthesis of nanoparticles

The rapid growth of nanotechnology is directly related to the ability to design novel materials at the nanoscale level alongside recent innovations in analytical and imaging technologies for measuring and manipulating nanomaterials. The rapid development of commercial applications involve the use of a wide variety of manufactured NPs. Nanotechnologies hold great promise for reducing the production of wastes, reducing industrial contamination and improving the efficiency of energy production and use. Nanoparticles can be synthesized by different methods such as physical, chemical and biological methods.

Physical approach:

In physical approach metal nanoparticles are synthesised by either evaporation - condensation method or laser ablation method. In evaporation condensation method the reaction is carried out using a tube furnace at atmospheric pressure. The target material is kept within a boat centred at the furnace is vaporized into a carrier gas. But this method has some drawbacks such as the tube furnace occupies a large space, consumes a great deal of energy raising the surrounding temperature around the source material and requires a lot of time to achieve the thermal stability. Kholoud *et al.,* 2010 synthesised silver nanoparticle by laser ablation method. The particles synthesised through laser ablation method depends upon the wavelength of the laser, the duration of the laser pulses the laser fluence, the ablation time duration and the effective liquid medium which may or may not containing the surfactant.

Chemical approach:

Chemical method is the most commonly used method for the synthesis of silver nanoparticles. The most commonly used reducing agents are sodium borohydride, hydrazine hydrate, potassium auro chlorate and sodium citrate. The reduction of various complexes with Ag+ ions leads to the formation of silver atoms (Ag^0), which is followed by agglomeration into oligomeric clusters. These clusters eventually lead to the formation of colloidal Ag particles.

Biosynthesis of nanoparticles:

Conventional procedures for nanoparticle synthesis incorporate physical or chemical routes and are very successful to produce well defined nanoparticles; they have certain limitations such as increase cost of production, release of hazardous by-products, long time for synthesis and difficulty in purification (Nagajyothi and Lee, 2011). To overcome these problems, there is an increasing need to develop high-yield, low cost, nontoxic, and environmentally benign procedures for synthesis of metallic nanoparticles. One of the objects of this research is to reduce the use of hazardous materials through alternative route on nanoparticle synthesis. Application of green chemistry principles to the field of nanotechnology was introduced by researchers about a decade ago. Eco-friendly, “green” nanotechnological processes are assumed to have the capability to produce new products by using ecofriendly materials. Such processes have involved plant metabolites and plant extracts and products of biological macromolecules such as nucleic acids, peptides or proteins, carbohydrates, and lipids as well. It is now well-proven that the biological route for synthesis of nanoparticles saves energy and creates comparatively less amount of harmful waste.

Biological approach for nanoparticle synthesis is an alternative way that is compatible with green chemistry principles, in which biomolecules secreted by the biomass can act as both reducing and capping agents during the reaction. Therefore, this reaction can be considered as a green chemical process that can minimize the usage of hazardous chemicals (Ahmad *et al*., 2010). A vast array of biological resources available in nature including plants and plant products, algae, fungi, yeast, bacteria, and viruses could all be used for synthesis of nanoparticles. Both unicellular and multicellular organisms have been known to produce intracellular or extracellular inorganic materials. From past several years’ bacteria, fungi, yeasts, algae and plants are used for synthesis of nanoparticles because of their spontaneous, economic, ecofriendly and non-toxic nature. A good number of researches are documented on the synthesis of nanoparticles from biological system for their applications in the field of biomedical, pharmaceutical, cosmetic and environmental use. Biosynthesis of nanoparticles can be used for bioremediation purpose because nanoparticles can diffuse or penetrate through the contaminants and cause a redox reaction to clean the surface materials. Nature plays vital role in synthesis of nano and micro sized materials which contribute to the development of relatively new and unexplored area of research based on the biosynthesis of nanomaterials.

Living cell ranges from prokaryotic to eukaryotic are typically 10 mm across. Many varieties of biological sources available in nature including bacteria, algae, yeast, fungi, lower plants and higher angiosperm plant products can all be involved for the synthesis of nanoparticles. These ambient biological systems provide excellent examples of nanophasic materials with highly optimized characteristics resulting from evolution over a long scale of time and the synthesis of inorganic materials may occur either extracellularly or intracellularly.

Biosynthesis of nanoparticles from Bacteria:

Use of microbial cells for synthesis of nano sized materials is considered as one of the novel approach for synthesis of metallic nanoparticles. Nanoparticles are biosynthesized when the microorganisms grab target ions from their environment and then turn metal ions into the elemental metal through enzymes generated by the cell activities. It can be classified into intracellular and extracellular synthesis according to the location where nanoparticles are formed (Simkiss & Mann, 1989). Conversion of nitrate to nitrite and the electron is transferred to the Silver ion causing the Silver ion to reduced Silver, which was observed in *Bacillus licheniformis* which is known to secrete NADPH and NADPH-dependent enzymes like nitrate reductase that effectively converts Ag^+ to Ag^0. The other example of bacteria involved in synthesis includes *Pseudomonas aeruginosa* (Husseiny *et al*., 2007), *Desulfovibrio desulfuricans* NCIMB 8307 (Yong *et al*., 2002).

Biosynthesis of Nanoparticles from Fungi:

Fungi can produce larger amounts of nanoparticles in comparison to bacteria because they can secrete larger amounts of proteins which directly translate to higher productivity of nanoparticles (Mohanpuria *et al*., 2008). Fungi can be described as the best nano-factories in relation to bacteria because they have high binding capacity with metal ions in intracellular region, they are easy to culture on solid substrate fermentation, and they can grow on the surface of inorganic substrate during culture leading to efficient distribution of metals as catalyst. (Ahmad *et al*., 2003) reported the synthesis of fabrication of extremely stable Ag hydrosol by using *Fusarium oxysporum* where the particles were stabilized by the proteins excreted through the fungus. Bhainsa *et al* has reported the extracellular biosynthesis of Ag particles in the 5-25 nm range using *Aspergillus fumigates.* (Vigneshwaran *et al*., 2006) reported the biomimetics of Ag nanoparticles by using *Phaenerochaete chrysosporium* commonly known as White rot fungus. Basavaraja *et al*., (2008) synthesized spherical and stable Ag nanoparticles in the range of 10-60 nm by using *Fusarium semitectum.* (Varshney *et al*., 2009) reported synthesis of Ag nanoparticles in the range of 20-80 nm by using a novel fungi *Hormoconis resinae*. The genus *Penicillium* seems to behave a superior contender for the Silver nanoparticle synthesis, where production proceeds via extracellular mechanism. The possible mechanism for the synthesis of Silver nanoparticle by fungi is said to follow the following steps: trapping of Ag+ ions at the surface of the fungal cells and the subsequent reduction of the Silver ions by the enzymes present in the fungal system (Mukherjee *et al*., 2001)

Biosynthesis of nanoparticles from Algae:

There are few reports of algae being used as a “biofactory” for synthesis of metallic nanoparticles. Recently, Singaravelu *et al*., 2007 adopted a systematic approach to study the synthesis of metallic nanoparticles by *Sargassum wightii* and Susan Azizi *et al*., 2013 synthesized Silver nanoparticles using *Sargassum muticum.* These were the first report in which a marine alga has been used to synthesize highly stable extracellular gold and silver nanoparticles in a relatively short time period compared with that of other biological procedures. Scarano and Morelli reported the fabrication of phytochelatin coated CdS nano crystals by using the phytoplanktonic algae *Phaeodactulum tricornatum.* Konishi *et al*., 2007 reported the synthesis of Pt nanoparticles of 5 nm from aqueous PtCl62- at neutral pH under room temperature by using *Shewanella algae*.

Biosynthesis of nanoparticles from Plants:

Various microorganisms such as bacteria, algae and fungi are used for the biosynthesis of nanoparticles but recently a new trend has come to force i.e., the use of plants for the fabrication of nanoparticles because of its spontaneous, economical, eco-friendly protocol, suitable for large scale production and single step technique for the biosynthesis process (Huang *et al*., 2007). The main mechanism considered for the synthesis of nanoparticles mediated by the plants is due to the presence of phytochemicals. The major phytochemicals responsible for the spontaneous reduction of ions are flavonoids, terpenoids, carboxylic acids, quinones, aldehydes, ketones and amides.

The first report of the plant employed in the synthesis of nanoparticles is attributed to Medicago sativa (alfalfa) which was capable of synthesizing gold and silver nanoparticles

(Gardea *et al*., 2003). Most of the studies confer the production of nanoparticles by plants that were known to be stable than nanoparticles synthesized by microorganisms (Iravani *et al*., 2011). The production of nanoparticles by plants relays on various factors among which, type of processing with optimized parameters is very much essential towards synthesis of nanoparticles such as growing plant in a media incorporated with raw material for the synthesis of nanoparticles, use of dried powdered plant material which is employed in the synthesis of plant material, drying plant material and evaluating nanoparticles synthesis, and employing fruits and flowers in the synthesis of nanoparticles .These different types of processing are known to influence nanoparticles' formation which has been reported in the various literature. A number of plants are being currently investigated for their role in the synthesis of nanoparticles such as *Cinnamomum camphora* leaf (Huang *et al*., 2007), *Pelargonium graueolens* leaf (Shankar *et al*., 2003), *Diospyros malabarica* (Desr.) Kostel. (Taranath *et al*., 2015), *Solanum seaforthianum* Andrews leaf (Basavarajeshwari *et al.*, 2016), *Cansjera rheedii* J. F. Gmel. (Irawwa *et al*., 2014), *Azadirachta indica leaf* (Shankar *et al*., 2004), *Emblica officinalis leaf* (Ankamwar *et al*., 2005), *Aloe vera leaf* (Chandran *et al*., 2006), *Alfalfa sprouts* (Gardea-Torresdey *et al*., 2003), *Helianthus annus, Basella alba, and Saccharum officinarum* (Leela *et al*., 2008), *Carica papaya callus* (Mude *et al*., 2009), *Jatropha curcas leaf (*Bar *et al*., 2009), *Glycine max (soybean) leaf* (Vivekanandan *et al*., 2009), *Coriandrum sativum leaf* (Sathyavathi *et al*., 2010), *Syzygium cumini leaf* (Kumar *et al*., 2010), *C*, *Argimone mexicana leaf* (Khandelwal *et al*., 2010), *Allium cepa* (Saxena *et al*., 2010), *Stevia rebaudiana leaves* (Varshney *et al.*, 2010), *Solanum torvum* (Govindaraju *et al*., 2010), *Zingiber officinale* (Singh *et al*., 2011), *Sesamum laciniatum* Klein ex Willd (Rokhade and Taranath 2014) *Capsicum annuum* (Li *et al*., 2007),, *Phytolacca decandra, Gelsemium sempervirens, Hydrastis canadensi (Pinus desiflora), Diopyros kaki, Ginko biloba, Magnolia kobus and Platanus orientalis* (Song *et al*., 2009), *Oriental plane* (Abdullah *et al*., 2017).

The synthesis of AgNPs & their antimicrobial activity was carried out by Jain *et al*., (2009) from *Carica papaya* L. plant extract. They have reported that synthesized AgNPs are cubic in nature with average particle size of 15 nm. They recorded that biologically synthesized AgNPs were found to be highly toxic against different multi drug resistant human pathogens.

Velusamy *et al*., (2015) synthesized *Azadirachta indica* mediated AgNPs and also tested their antimicrobial activity. The synthesized silver nanoparticles were monodispersed and spherical particles with an average size < 30 nm. The antibacterial activity of the synthesized nanoparticles was confirmed by degradation of test bacterial DNA. Their results showed that the gum mediated synthesized silver nanoparticles could be used as a antibacterial agent against clinical pathogens.

Allium cepa mediated AgNPs synthesized by Saxena *et al*., (2010) and they also studied the antibacterial activity. The synthesized silver nanoparticles were 33.6 nm in averages mean size and showed antibacterial activity against *E.coli* and *Salmonella typhimurium*. The bactericidal property of nanoparticles was examined by measuring the growth curve of bacteria in presence of 50 μg/ml concentration of silver nanoparticles.

Andrographis paniculata aqueous extract mediated AgNPs was synthesized by Sinha and Paul (2015) and they also studied the antimicrobial activity against various bacterial strain. The size of the synthesized silver nanoparticles was in between 40 and 60 nm. They recorded that the antibacterial activity of the synthesized nanoparticles is promising against *Pseudomonas aeruginosa* among the bacteria tested.

Biosynthesis of nanoparticles and their antimicrobial activity described by Singhal *et al*., (2011). They recorded that *O. sanctum* leaf extract can reduce silver ions into silver nanoparticles within 8 min of reaction period. Biosynthesized silver nanoparticles are in the size range of 4–30 nm and possessed antimicrobial activity. They showed silver nanoparticles were exhibit more antimicrobial activity on gram-negative microorganism than gram-positive bacteria and also showed synthesized silver nanoparticles have stronger activity than silver nitrate and standard antibiotic ciprofloxacin.

Saikia *et al*., (2015) recorded the green synthesis of silver nanoparticles using *Asiatic Pennywort* and *Bryophyllum* leaf extracts as reducing and capping agents. Their synthesized silver nanoparticles have average sizes 18-21 nm. They also explained the size dependent antimicrobial activities of silver nanoparticles against gram negative bacteria *Pseudomonas Fluorescens* and gram positive bacteria *Staphylococcus epidermidis*. They recorded that silver nanoparticles obtained from *Asiatic pennywort* was more effective on gram positive bacteria while silver nanoparticles obtained from *Bryophyllum* was more effective on gram negative bacteria.

Biosynthesis of nanoparticles and their antimicrobial activity by using bark extract and powder of *Cinnamon zeylanicum* was reporded by Sathishkumar *et al*., (2009). The average size of the nanoparticles ranged between 31 and 40 nm. They showed that pH played a major role in size control of the particles and also bark extract are more effective silver nanoparticles producer than the powder. The synthesized nanoparticles showed an EC50 value of 11±1.72 mg/L against *Escherichia coli* BL-21 strain. So, the bark extract is good source of biosynthesis of silver nanoparticles and synthesized nanoparticles can be used as a potential antimicrobial agent.

Sarkar *et al*., (2010) recorded the synthesis of silver nanoparticles of varying sizes using *parthenium* leaf extract at a higher temperature of 100 °C as well as at room temperature. They showed the variation of particle size with the reaction temperature and reaction time. The synthesized colloidal silver nanoparticles were photo-luminescent. The size of the silver nanoparticles synthesized after 2 minutes of chemical reaction at a higher temperature of 100° C lie within 40-160 nm and the average size of the nanoparticles was ~ 110 nm.

The use of plants for the production of silver nanoparticles has received lots of attention due to its rapid, eco-friendly, non-pathogenic, economical protocol and providing a single step technique for the green synthesis processes (Huang *et al*., 2007). The reduction and stabilization of silver ions by combination of biomolecules such as proteins, amino acids, enzymes, polysaccharides, alkaloids, tannins, phenolics, saponins, terpinoids and vitamins which are already established in the plant extracts having medicinal values and are environmental benign, yet chemically complex structures (Kulkarni *et al*., 2014).

CONCLUSION

Green synthesis of nanoparticles has been an emerging research area now a day. The advancement of green syntheses over chemical and physical methods is environment friendly, cost effective and easily scaled up for large scale syntheses of nanoparticles, furthermore there is no need to use high temperature, pressure, energy and toxic chemicals.

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