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International Journal of Current Research in Life Sciences
Vol. 07, No. 04, pp.1927-1932, April, 2018

ISSN: 2319-9490

REVIEW ARTICLE

BIO-FABRICATION OF METAL NANOPARTICLES: A REVIEW

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Received 22nd February, 2018; Accepted 18th March, 2018; Published 30th April, 2018

ABSTRACT

In last few years nanotechnology has received particular interest in a wide range of fields. The term "nano" comes from the Greek word "nano" meaning dwarf and denotes a measurement on the scale of one-billionth (10^{-9}) of a metre in size. It is a branch of science, which deals with nano level substances. It widely covers the synthesis of materials (organic & in-organic) at neno scale and their application in various sectors like electronics, computers, sensing, solar energy, biomedical sciences, medicine, instrumentation etc. Synthesis of nanoparticles can be done by various approaches like physical and chemical, which covers several types of methods but these methods have drawbacks such as the use of toxic chemicals and the high-energy requirements of production. So an alternative way of synthesising metallic nanoparticles is by using biological approach for synthesis of nanoparticles is highly focused by scientific community. This includes the microbial synthesis and green synthesis. This review majorly provides the information about the biological sources, which could be used for synthesis of metallic nanoparticles. It could provide the better insight for the bio-assisted synthesis of metal nanoparticles.

Key words: Biological Synthesis, Nanoparticles, Green synthesis.

Citation: Vikas Shrivastava, Pallavi Singh Chauhan and Rajesh Singh Tomar, 2018. "Bio-Fabrication of metal nanoparticles: A review" *International Journal of Current Research in Life Sciences*, 7, (04), 1927-1932.

INTRODUCTION

There are various methods available for the synthesis of inorganic metal nanoparticles such as physical method, chemical method and biological method (microbial assisted synthesis and plant mediated synthesis). Physical method of synthesis includes laser pyrolysis, laser ablation, ball milling, condensation, evaporation lithography etc. (Mitrakos *et al.,* 2008; Zamiri *et al.,* 2012; Mafune *et al.,* 2001; Zhang and Wang, 2008 and Treguer *et al.,* 1998). Chemical method of synthesis include use of harsh chemical agents such as hydrazine, sodium borohydride, sodium hydroxide, potassium hydroxide for reduction purpose as well as toxic chemicals for capping purpose (Chen *et al.,* 2001; Eustis *et al.,* 2005; Rodríguez-Sanchez *et al.,* 2002; Starowiicz *et al.,* 2006 and Frattini *et al.,* 2005). Both the methods have potential risk of hazards such as toxicity, carcinogenicity etc. (Ai *et al.,* 2011). These properties of the synthesized nanoparticles from conventional methods have prevented them from using into biomedical and clinical applications. Thus there is a prerequisite to develop a bio-compatible, eco-friendly, reliable and clean method for nanoparticles synthesis called Biological synthesis. The biological system of synthesis includes plants, bacteria or fungi, which is an easy and viable alternative approach to synthesize metallic nanoparticles (Du *et al.,* 2007).

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Biological Methods of Nanoparticles Synthesis

Microbial synthesis

The fungal species improves the mass production of silver nanoparticles. When as a source of energy it was grown on elemental sulfur it causes reduction of ferric ion in the presence of *Thiobacillus* species. Metal contaminated soil was used for isolation of bacterial strain (CS 11) for the synthesis of silver nanoparticles extracellularly at room temperature (Das *et al.,* 2014). Aqueous extract of the seaweed *Turbinaria conoides* was used to synthesize Silver and gold nanoparticles (Vijayan *et al.,* 2014). The silver nanoparticles were synthesized using Extracellular agents produced from isolated bacterial strains such as *Bacillus pumilus, B. persicus,* and *Bacillus licheniformis* (Elbeshehy *et al.,* 2015). Silver nanoparticles were synthesized using a novel method using culture supernatant of phenol degraded broth (Otari *et al.,* 2014). Silver nanoparticles were synthesized extracellularly by cell filtrate of *Myxococcus virescens* (Wrótniak –Drzewiecka *et al.,* 2014). *Aspergillius tubingensis* TFR-5 (NCBI GenBank Accession No. JQ675306) used for the synthesis of phosphorous nanoparticle using tri calcium phosphate (Tarafdar *et al.,* 2012). *Hypocrea lixii* was used for the uptake and production of nickel oxide nanoparticles (Salvadori *et al.,* 2015). Endophytic Colletotrichum sp. ALF2-6 was used to synthesis silver nanoparticles (Azmath *et al.,* 2016).

Proteus mirabilis was used for the biosynthesis of AgNPs and its preliminary toxic effects were determined (Al-Harbi *et al.,* 2014). Silver nanoparticles were synthesized using crude extracellular keratinase, obtained from *Bacillus safensis* LAU 13 (GenBank accession No. KJ461434) (Lateef *et al.,* 2015). Silver nanoparticles were synthesized using two different microbial strains i.e. fungi *Penicillium expansum* HA2N and *Aspergillus terreus* HA1N (Ammar *et al.,* 2016).

Green synthesis

Green synthesis explores the utilization of plant diversity for synthesizing nanoparticles which is a rapid and single step method. Green principles have added advantages over the conventional methods available for synthesizing nanoparticles (Ahmed *et al.,* 2016). Green synthesis is simple, it involves a one-pot reaction, easily scaled up amenable to scale up, less

i.Fabrication of Nanoparticles Using Bacteria:
Here are some examples of bacterial synthesis of metal nanoparticles listed in Table 2.1 below:

Table 2.1. Fabrication of Nanoparticles Using Bacteria

S.no.	Microbial strain	Metal nanoparticles	Reference
1.	*Pseudomonas stutzeri AG259*	Ag particles	[24]
2.	*Lactobacillus*	Au and Ag NPs	[25]
3.	*Klebsiella pneumonia, Escherichia coli and Enterobacter Cloacae*	Ag NP's	[26]
4.	*Klebsiella pneumonia*	Ag NP's	[27]
5.	*Bacillus Licheniformis*	Ag Np's	[28]
6.	*Pseudomonas stutzeri*	Cu NP's	[29]
7.	*Pseudomonas Stutzeri*	Cu NP's	[30]
8.	*Bacillus cereus*	Ag NP's	[31]

ii.Fabrication of Nanoparticles Using Yeast:
Here are some examples of synthesis of metal nanoparticles by yeast as listed in table

Table 2.2. Fabrication of Nanoparticles Using Yeast

S.no.	Microbial strain	Metal nanoparticles	Reference
1.	*Yeast strain MKY3*	Ag NP's	[32]
2.	*Pichia jadinii*	Au NPs	[33]
3.	*Candida glabrata*	CdS NPs	[34]
4.	*Yarrowia lipolytica NCIM3589*	Au NPs	[35]
5.	*Schizosaccharomyces pombe*	CdS NPs	[36]

iii.Fabrication of Nanoparticles Using Algae:
Here are some examples of synthesis of metal nanoparticles by Algae as listed in table below:

Table 2.3. Fabrication of Nanoparticles Using Algae

S.no.	Microbial strain	Metal nanoparticles	Reference
1.	*Sargassum wightii*	Ag NP's	[37]
2.	*Nannochloropsis oculata and Chlorella vulgaris*	Ag NP's	[38]
3.	*Sargassum muticum*	Au NP's	[39]
4.	*Stoechospermum marginatum*	Au NP's	[40]
5.	*Chlamydomonas reinhardtii*	Ag NP's	[41]
6.	*Turbinaria conoides*	Ag NP's	[42]
7.	*Bifurcaria bifurcate*	Cu NP's	[43]
8.	*Sargassum muticum*	Zn NP's	[44]
9.	*Sargassum muticum*	Fe NP's	[45]

iv.Fabrication of Nanoparticles Using Fungi:
Here are some examples of synthesis of metal nanoparticles by Fungi as listed in table below:

Table 2.4. Fabrication of Nanoparticles Using Fungi

S.no.	Microbial strain	Metal nanoparticles	Reference
1.	*Aspergillus fumigates*	Ag-NPs	[46]
2.	*Phaenerochaete chrysosporium*	Ag-NPs	[47]
3.	*Aspergillus flavus*	Ag-NPs	[48]
4.	*Fusarium acuminatum*	Ag-NPs	[49]
5.	*Fusarium semitectum*	Ag-NPs	[50]
6.	*Fusarium solani*	Ag-NPs	[51]
7.	*Penicillium fellutanum,*	Ag-NPs	[52]
8.	*Phoma glomerata*	Ag-NPs	[53]
9.	*Fusarium, Aspergillus and Penicillium*	Ag-NPs	[54]
10.	*Hormoconis resinae*	Ag-NPs	[55]
11.	*Aspergillus terreus*	Ag-NPs	[56]
12.	*Helminthosporum solani*	Au- NPs	[57]
13.	*Neurospora crassa*	Au- NPs	[58]
14.	*Cylindrocladium floridanu*	Au- NPs	[59]

Table 2.5. Nanoparticles Synthesis Using Higher Angiosperm Plants

S.no.	Plant species	Metal nanoparticles	Reference
1.	*Geranium sp.*	Ag-NPs as well as Au-NPs	[72]
2.	Leaf broth of *Azadirachta indica*	Ag, Au- NPs and bimetallic Au/Ag NPs.	[73]
3.	Fruit extract of *Emblica officinalis*	Ag and Au-NPs	[74]
4.	Leaf extract of *Aloe vera*	Au nano triangles and Ag-NPs	[75]
5.	*Cinnamomum camphora*	Au and Ag-NPs	[76]
6.	*Medicago sativa*	Ag-NPs	[77]
7.	*Pelargonium graueoleus* leaf extract	Ag-NPs	[78]
8.	Leaf extracts of *Saccharum officinarum,* and *Helianthus annus, Basella alba,*	Ag-NPs	[79]
9.	Callus extract of *Carica papaya*	Ag-NPs	[80]
10.	*Jatropha curcas*	Ag-NPs	[81]
11.	*Eclipta* leaf	Ag-NPs	[82]
12.	Leaf extract of *Glycine max*	Ag-NPs	[83]
14.	Leaves of *Stevia rebaudiana*	Ag-NPs	[84]
15.	*Solanum torvum*	Ag-NPs	[85]
16.	Soybeans extract	Cu NP’s	[86]
17.	*Zingiber officinale*	Ag-NPs	[87]
18.	Leaf extract of *Mangolia*	Cu NP’s	[88]

toxic, bio compatibility is more for *in vivo* applications, provide stability to nanoparticles, cost effective (Schröfel *et al.,* 2014). The reduction of metal ions is done by employing various bio molecules, like amino acids, proteins, enzymes etc. Reported for having medicinal importance along with eco friendly (Kulkarn and Muddapur, 2014). Silver nanoparticles fabricated using leaf as well as stem extract of *Piper nigrum* (Paulkumar *et al.,* 2014). Gold nanoparticles were fabricated using different plant extracts *Lippia citriodora, Salvia officinalis,* and *Punica granatum* (Elia *et al.,* 2014). Silver nanoparticles were prepared using *Chrysanthemum indicum*, which is simple, cost-effective, and ecofriendly approach (Arokiyaraj *et al.,* 2014). Magnetite nanoparticles (Fe3O4-NPs) were synthesized using Seaweed *Kappaphycus alvarezii* as a source of stabilizing and reducing agents (Yew *et al.,* 2016). Microwave assisted method was used to prepare silver nanoparticles using aqueous leaf extract of *Eucalyptus globules* (Ali *et al.,* 2015). Gold nanoparticles were synthesized using ethanol *Syzygium aromaticum* extract and were studied for their anticancer potential in SUDHL-4 cell line (Parida *et al.,* 2014). Activated sludge was used to isolation of *Acinetobacter* sp. SW 30 which were used for intracellular synthesis of gold nanoparticles under various physiological parameters. The synthesized gold nanoparticle has wide application in cancer treatment, drug delivery as well as in nanobiosensor. From silver nitrate, Silver nanoparticles were synthesized using *Sinapis arvensis* (Khatami *et al.,* 2015). Silver nanoparticles were synthesized extracellularly using gram positive *Streptomycetes* isolated from rice fields (Nejad *et al.,* 2015). Silver nanoparticles were prepared using extract of two plant part of *Piper nigrum* i.e. leaf and stem (Paulkuma *et al.,* 2014). Fabrication of Nanoparticles Using Higher Angiosperm Plants:

Here are some examples of synthesis of metal nanoparticles by Higher Angiosperm Plants as listed in table above

Conclusion

Ever-growing awareness about the necessity to turn towards environment-friendly approaches for materials synthesis to protect earth’s environment has led to the development of eco-friendly, safe and green biological methods for nanoparticle production. Unlike other physical and chemical processes which involve the use expensive and sometimes hazardous chemicals and equipments, biological processes are cost-effective and eco-friendly. These drawbacks necessitate the development of nonhazardous and biological methods for nanoparticles synthesis.

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