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A Review on Green Synthesis of Silver Nano-Particles: An Eco-Friendly Approach

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Abstract: **Microbial contamination of drinking water poses serious health problem therefore disinfecting water by removing or killing harmful microorganism is of great importance. Common water disinfection methods include chemical disinfection, filtration, and UV disinfection. However recent research has revealed that, chemical disinfectants such as ozone, chlorine and chloramines, react with various constituents in natural water, forming disinfection by-products (DBPs). Although UV-disinfection and filtration methods are effective in eliminating microbial contamination, but their operational costs are very high and some procedures can be quite time-consuming. Recently, nanotechnology has opened an alternative method of water disinfection. Unlike the chemical disinfectants, the known antimicrobial nanomaterials are relatively inert in water and are not expected to form harmful DBPs. Nanotechnology is a field of science deals with the Nanoparticles having a size of 1-100 nm in one dimension. Nanoparticles can be broadly classified into organic nanoparticles which include carbon nanoparticles; inorganic nanoparticles include magnetic nanoparticles, metal nanoparticles which includes gold and silver nanoparticles and semi-conductor nanoparticles like titanium oxide and zinc oxide nano particles. Among these nanoparticle silver nanoparticles are the most promising one due to their strong antimicrobial activity towards many different bacteria, fungi, algae, and viruses and their relatively low toxicity to humans and also environmental friendly and very cheap. This review focuses on the green synthesis of silver nanoparticles, the mechanisms involved in its antimicrobial activity, its importance/application in commercial as well as biomedical fields discussed in detail.**

Keywords: **Antimicrobial properties, Applications, Characterization techniques, Green synthesis, Methods.**

1. INTRODUCTION

WATER is one of the essential enablers of life on earth (Bhoominathan Srinivasan 2015). An adequate supply of safe drinking water is one of the greater prerequisites for a healthy life (John Fawell et al., 2003), but waterborne disease is still a major cause of death in many parts of the world, therefore disinfecting water by removing, or killing harmful microorganism is of great importance (Ping Y. Furlan et al., 2017) . Conventional water treatment techniques including reverse osmosis, distillation, bio-sand, coagulation-flocculation and filtration are not capable of removing all heavy metal ions (Gholamreza ghasemzadeh et al., 2014) and chlorination and ozonation consume a high amount of chemical agents and, furthermore, can produce toxic byproducts(Ilka Gehrke et al 2015). Consequently, selecting a suitable disinfectant depends on technical dependability, economic and environmental criteria. Many problems involved in water quality could be obviated or greatly improved using products and processes resulting from the progression of nanotechnology and engineering processes. In recent years, nanoparticles were focused on a wide range of research areas, especially environmental issues (Mohammad Ali Zazouli et al., 2017). Application of nano-scale materials, ranging from 1–100 nm, is an emerging area of nanotechnology (Eman Azarani et al., 2014). Nanoparticles can be synthesized using various approaches including chemical, physical and biological methods (P.ananthi et al., 2016). Biological method of synthesis of nanoparticles plays a significant importance in solving current day problems (shokkannabasker et al., 2016). Biological methods provide various advantages including cost effective, simple and green biocompatibility plant mediated synthesis of nanoparticles has

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generated wide interest owing to its inherent features such as rapidity, simplicity, eco-friendliness and cheaper costs (selvaraj raja et al., 2015). Different types of nanoparticles existed like metal, metal oxides, semiconductors, polymer, and core shell particles (S. Rajeshkumar 2016). Among these Metal nanoparticles such as gold and silver have been recognized to be important in the fields of chemistry, physics and biology (Dr. Ananada.S 2013). One such important member of the noble metal NPs are silver NPs (Ag NPs). They are also broadly applied in shampoos, soaps, detergents, cosmetics, toothpastes and medical and pharmaceutical products and are hence directly encountered by human systems. Earlier, the antifungal properties of silver and silver nitrate were well incorporated in the field of medical science. Also, the medicinal importance of innumerable plants and plant parts were known (Priya Banerjee et al., 2014).

2. METHODS TO SYNTHESIZE NANOPARTICLES

2.1 Physical Method:

In physical processes, metal nanoparticles are generally synthesized by evaporation–condensation, which could be carried out using a tube furnace at atmospheric pressure (Kholoud M.M. Abou El-Nour et al., 2010).

2.2 Chemical Method:

Recently, biosynthetic methods using naturally reducing agents such as polysaccharides, biological microorganism such as bacteria and fungus or plants extract, i.e. green chemistry, have emerged as a simple and viable alternative to more complex chemical synthetic procedures to obtain AgNPs. Bacteria are known to produce inorganic materials either intra- or extracellularly. This makes them potential biofactories for the synthesis of nanoparticles like gold and silver. Particularly, silver is well known for its biotical properties (Jun Natsuki et al., 2015).

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3. GREEN SYNTHESIS OF SILVER NANOPARTICLES

Nanoparticles can be synthesized by using three methods such as physical, chemical and biological. The physical method includes ball milling of bulkmaterial to nanoscale size. The chemical methods involve sono-chemical process. Plants and microbes such as bacteria, yeast, and fungi are used in the biological method synthesis of nanoparticle. (Michael Ndikau et al 2016). Physical and chemical methods have usually been successful in the synthesis of nanomaterials in large quantities in short periods of time, as well for specific size and shape. However, most of these methods are extremely expensive and they also involve the use of toxic, hazardous chemicals as the stabilizers which may pose potential environmental and biological risks.In recent years, the use of biological methods for the synthesis of metallic nanoparticles has received considerable attention (A. R. Allafchian et al., 2016).The synthesis of silver nanomaterials using biological entities is gaining momentum as; biological methods are providing, nontoxic and environmentally acceptable “green chemistry” procedures (Nafeesa Khatoon et al., 2017).

A naturally motivated investigational practice for the biosynthesis of NPs is now established as an emerging area of nanoscience research and development. In nanotechnology nanoparticles can be broadly classified into organic nanoparticles like carbon nano-particles, inorganic nanoparticles like magnetic nanoparticles, Metal Oxides nanoparticles like TiO2 nanoparticles, ZnO nanoparticles, and Iron Oxides nanoparticles, and Zero-Valent Metal nanoparticles like silver and gold nanoparticles. Among these Silver nanoparticles (Ag NPs) are highly toxic tomicroorganisms and thus have strong antibacterial effects against a wide range of microorganisms, including viruses, bacteria, and fungi. As a good antimicrobial agent, silver nanoparticles have been widely used for the disinfection of water (Haijiao Lu et al., 2016)..Silver nanoparticles have a potential ability to kill over 650 different bacteria (Dr Ananada s 2013). Recent literature reveals the use of leaf extract from various plants such as Azadirachta indica, Delonix elata, Tephrosia purpurea, Melia dubia, Tribulus ter-

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restris, Artemisia nilagirica, Boerhaavia diffusa, Ficus religios, Piper pedicellatum C.DC and Melia azedarach L, as sources for synthesis of silver nanoparticles (Selvaraj Raja et al., 2017). AgNPs have also been synthesized using various plants like, Acalypha indica, Parthenium hysterophorus, Aloe barbadensis, and Gliricidia sepium (shokkanna basker et al., 2016). Silver Nanoparticles synthesized extracts of different plants from various families and the size and shape of the nanoparticles is shown in below table 1.

Table 1: shows Silver Nanoparticles synthesized extracts of different plants from various families and the size and shape of the nanoparticles obtained.

Author	Name of the plant	Characterization technique used	Particles characterization
R. sithara et al., (2017)	Acalyphahispida	UV-Vis, XRD,FTIR And TEM	Size: 20-50nm Structure:crystalline
Kalaiselvi mani et al., (2017)	Parthenium hysterophorous	UV-Vis, XRD, FTIR and AFM	Size: 10.4nm(boiled) 10.7nm(groumded)
Arinjioy Datta et al., (2017)	Parthenium hysteroporous	SEM, TEM, FTIR, EDX And UV-Vis	Shape:spherical and cylindrical Size:16-45nm
A.R.Allafchian et al., (2016)	Pholomis	SEM, TEM, FTIR, XRD And UV-Vis	Shape: spherical Size:25nm
Alagan geevika et al., (2016)	Terminalia bellerica	HR-TEM, XRD And FTIR	Shape:spherical Structure:FCC
P.Ananthi et al., (2016)	Tricumfetta rotundifolia	UV-Vis, XRD, FTIR,And HR-SEM	Structure:FCC Shape:rod, cylindrical Range:20-100nm
P.S.Ramesh et al., (2015)	Embilica officinalis fruit	UV-Vis, XRD, FTIR, SEM And AFM	Avg size: 15nm Structure:crystaline,
K.Saminathan et al., (2015)	Ecliptaalba	UV-Vis, XRD, FTIR, SEM And DLS	Size: 60nm
B.Syama Sundar et al., (2015)	Azadirchta indica	UV-Vis, SEM, XRD, TEM FTIR And HR-TEM	Size: 15 and 27nm
Sumi maria et al., (2014)	Zizyphus xylopyrus	UV-Vis, SEM And XRD	Size:60-70nm Shape:spherical
Thombr we al., (2013)	Parthenium hysterophorous L.	UV-Vis, XRD, FTIR, EDS And SEM	Size: 20-50nm
Dr.Ananda S et al., (2013)	Parthenium hysterophorous	UV-Vis, XRD, SEM And TEM	Size: 10nm

4. CHARACTRIZATION TECHNIQUES FOR SYNTHESIS OF SILVER NANOPARTICLES

Characterization is an important step to identify the nanoparticles by their shape, size, surface area and dispersity (Swarup Roy et al., 2015). Characterization of nanoparticles is important to understand and control nanoparticles synthesis and applications (Jun Natsuki et al., 2015). Characterization is performed using a variety of analytical techniques, including UV-vis spectroscopy, X-ray diffractometry (XRD), Fourier transform infrared spectroscopy (FTIR), X-ray photoelectron spectroscopy (XPS), dynamic light scattering (DLS), scanning electron microscopy (SEM), transmission electron microscopy (TEM), and atomic force microscopy (atm) (Xi-Feng Zhang et al., 2016).

4.1 UV-Vis Spectrophotometer:

UV-Vis spectrophotometer allows identification, characterization and analysis of metallic nanoparticles (swarup Roy et al., 2015).

4.2 SEM and TEM:

The morphology of AgNPs is obtained using transmission and scanning electron microscopy (Jun Natsuki et al., 2015).

4.3 Zeta Potential Measurement:

The size distribution of AgNPs can be measured with a Zetasizer Nano Series analyzer (Jun Natsuki et al., 2015).

4.4 X-Ray Diffraction (XRD):

XRD is used to examine the overall oxidation state of the particles as a function of time, i.e. phase identification and characterization of the crystal structure of the nanoparticles (swarup Roy et al., 2015).

4.5 Dynamic Light Scattering (DLS):

DLS can probe the size distribution of small particles a scale ranging from submicron down to one nanometer in solution or suspension (Xi-Feng Zhang et al., 2016).

4.6 Atomic Force Microscopy (AFM):

Generally, AFM is used to investigate the dispersion and aggregation of nanomaterials, in addition to their size, shape, sorption, and structure; three different scanning modes are available, including contact mode, non-contact mode, and intermittent sample contact mode. AFM can also be used to characterize the interaction of nanomaterials with supported lipid bilayers in real time, which is not achievable with current electron microscopy (EM) techniques (Xi-Feng Zhang et al., 2016).

4.7 Energy Dispersive Spectroscopy (EDS):

To know the elemental composition of metal nanoparticles EDS is used, which gives the elemental knowledge of sample (swarup Roy et al., 2015).

4.8 Localized Surface Plasmon Resonance (LSPR):

LSPR is a coherent, collective spatial oscillation of the conduction electrons in a metallic nanoparticle, which can be directly excited by near-visible light. The localized surface Plasmon resonance (LSPR) condition is defined by several factors, including the electronic properties of the nanoparticle, the size and shape of the particle, temperature, the dielectric environment, and so on (Xi-Feng Zhang et al., 2016).

4.9 Fourier Transforms Infrared Spectroscopy (FTIR):

FTIR IS used for detection of various functional bonds in both the extracts and the nanoparticles being synthesized (Ibironke A. Ajayi et al., 2015).

4.10 Scanning Tunnelling Microscopy (STM), Atomic Force Microscopy (AFM):

AFM and STM provide surface characterization at the atomic scale (swarup Roy et al., 2015).

5. APPLICATIONS OF SILVER NANOPARTICLES

Nanotechnology applications are highly useful for biological molecules because of their unique properties. It is a growing field of material science and biological science. AgNPs have broad applications in diverse areas such as integrated circuits, biolabeling filters, antimicrobial deodorant fibers, cell electrodes, and low cost paper batteries. It also has important role in health industry, food industry, textile coatings, and environmental applications (Antony et al., 2016). Recently it has been used in many consumer products like soap, toothpaste, and socks due to its antimicrobial properties. And also, it has been used in water purification systems, medical devices, cosmrtics, bioremediations, heavy metal and peasticide removal in water and soil (S. Rajeshkumar 2016).

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6. ANTIMICROBIAL PROPERTIES OF SILVER NANOPARTICLES

6.1 Antibacterial Activity of AgNPs:

AgNPs seem to be alternative antibacterial agents to antibiotics and have the ability to overcome the bacterial resistance against antibiotics. Therefore, it is necessary to develop AgNPs as antibacterial agents. Among the several promising nanomaterials, AgNPs seem to be potential antibacterial agents due to their large surface-to-volume ratios and crystologrofic surface structure (Xi-Feng Zhang et al., 2016).

6.2 Antifungal Activity of AgNPs:

Silver nanoparicles formulation on a total of 44 antifungal stratins of six fungal species. One of the most common pathogens responsible for fungal infections is Candida species. It often causes nosocomial infection with an associated mortality rate of up to 40%. Hence AgNPs is considered as potent and a fast-acting fungicide against broad spectrum of common fungi including Aspergillus, Candida and Saccharomyces (Nafeesa Khatoon et al., 2017).

6.3 Antiviral Activity of AgNPs:

In recent years, there was an increase in reported numbers of emerging and re-emerging infectious diseases caused by viruses such as SARS-Cov, influenza A/H5N1, influenza A/H1N1, Dengue virus, HIV, HBV, and new encephalitis viruses etc. These viral infections are likely to break out into highly infectious diseases endangering public health (Quang Huy Tran et al., 2013).

7. CONCLUSION

From the studies we came to know that green chemistry apporaoach for the synthesis of silver nanoparticles is beneficial, uncomplicated, energy coefficient, low cost and environmental friendly. These metal nanoparticles have high specific surface area due to their unique optical, electronics, catalytic, anti-bacterial and magnetic properties. The silver nanoparticles can be synthesized by using chemical, physical and biological methods. Among these the biological synthesis of silver nanoparticles using plant extract, is an advantageous method over physical and chemical as it is cost effective, and there is no use of any toxic chemicals for the synthesis of nanoparticles. The synthesized silver nanoparticles using biological method shows wide range of variation in size and shape. They found emerged in present and future era, with variety of applications in many fields of high sensitivity bio molecular detection and diagnostics, antimicrobials, catalysis, micro-electronics and therapeutics, agriculture and water treatment and more. Various characterization techniques have been used for confirmation and synthesis of silver nanparticles. Biological synthesis of silver nanoparticles shows excellent antimicrobial properties.

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