

REVIEW ON GREEN SYNTHESIS OF SILVER NANOPARTICLES: METHOD, APPLICATION AND TOXICITY

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ABSTRACT

Silver nanoparticles has gained top most popularity in health care sector as well as other various fields including textile, cosmetics and agriculture. Due to its potential various methods of synthesis were developed such as chemical, physical and green synthesis. In this articles advantages of various green synthesis method is highlighted over chemical and physical method along with its source and applications. Green synthesis is economical and ecofriendly. It devoids of toxic chemicals and products as that of chemical and physical methods of synthesis. The aqueous extract which are obtained from plants used in the synthesis of silver nanoparticles. Extract it self acts

as a reducing agent and a capping agent, which leads to formation of stable silver nanoparticles. Application of stable silver nanoparticles in the various fields including the textile, cosmetics, and agriculture which are also reviewed in this articles. Silver nanoparticles is now coming put forth as potential antimicrobial agent and anticancer agents. Multidrug resistance bacteria also can be treated by silver nanoparticles. In future silver nanoparticles may acts as the new generation aid for the treatment of various disease conditions including cancers also.

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INTRODUCTION

Fast few years noble metals like silver Gold and palladium have drawn attention because of their wide range of applications. Nanoparticles of these metals are showing tremendous applications in various fields. Profoundly, silver nanoparticles have significant interest in medical field.^[1]

Silver nanoparticles mainly used in many fields including healthcare, medicines, industrial purpose and other fields. Reduction in size changes various properties of silver metal including electrochemical and physical. The methods for synthesis are chemical, physical and biological. Despite of various disadvantages of these two methods, they are widely used. But now-a-days green synthesis is replacing these methods.^[2]

Silver nanoparticles mainly shows antimicrobial and anticancer properties. Antimicrobial property depends on size, smaller the size higher the antimicrobial property. Silver nanoparticle has various properties such as electrochemical and physical. Size shape and size distribution these are physical properties which depends on method of synthesis. In chemical method reducing agent and stabilizer are important factors.^[3] One of the chemical method is by using ammonia. Liquid Ammonia act as reducing agent. It reduces metal precursor like silver nitrate into nanoparticles. Another more common reductants are alcohol hydrazine and hydro borate.^[4] Sometime green synthesis was mis concept with Chemical synthesis like synthesis by using oxalic acid.^[5] Along with antimicrobial properties silver nanoparticles also play roll in wound healing process. It has been proven beneficial for patient suffering from diabetes and having some other problems.^[6] Silver nanoparticle shows broad spectrum of antimicrobial activity it shows bactericidal properties. Silver nanoparticle act against multidrug resistance bacteria.^[7] Silver nanoparticle shows size dependent activity. Various shape and size of nanoparticle possesses various type of action. Control over shape and size is done by controlling reducing agent metal precursor salt and stabilizing agent. Also method of synthesis play important role.^[8] Various technical advantages has been observed over silver metal as compared to silver nanoparticles.^[9]

Methods of Synthesis

1. Physical method
2. Chemical Method
3. Green synthesis

Physical Method^[3,10,11,12]

Basically evaporation and condensation method was used in physical method. Atmospheric pressure is used. Silver metal was firstly vaporized by using strong furnace and carrier gas. Controlled condensation of it give silver nanoparticles. Another method was electrochemical method. Electrochemical property and magnetic field used to synthesise silver nanoparticles. Nanoparticles formed by this method show uniform size distribution. But high energy has been required.

Photo reduction method is one of the best physical method to synthesise silver nanoparticles. This method synthesized nanoparticles embedded in nafion. Light source such as UV light at 365 NM has used to accelerate the photo reduction process.

Another finest approach was sparking method. This method includes continuous deposition of metal precursor by varing number of sparking cycles. Silver nanoparticles has been deposited on the glass substrate and annealing at 250 t o 500 degree Celsius for about 1 hour. This is how silver nanoparticles has been synthesized by sparking method.

Chemical Methods

Chemical method is easy method for synthesis of silver nanoparticles. Mainly three components are involved in synthesis of nanoparticles by this method. Metal precursor in (Silver Nitrate), a reducing agent, and stabilizing or capping agent. Silver nanoparticles are formed by Two Steps that are first nucleation and second growth. First of all nucleus that is ions of silver metal subsequently aggregate and grow to give finite size silver nanoparticles.^[13] Chemical method is costly it also involves use of toxic hazardous chemicals and this may lead to potential hazards to the environment. Besides this various other side effects are also there. In biological method or green synthesis the collection of enzymes especially nitrate reductase enzymes plays a major role.^[14]

Nanoparticles were also prepared by using oil. Oleic acid coated silver nanoparticles were lipophilic in nature. Use of Oleic acid was to stabilize the silver nanoparticles. Oil face used

as solvent and silver nitrate as precursor which was then reduced to Silver nanoparticles in co-existing aqueous face.^[15]

Sono electrochemical method was employed for the synthesis of ultrafine silver nanoparticles. Nanoparticles formed by this method has diameter less than to 10 NM in 0.1 molar HCL aqua. This method do not employ any kind of stabilizer.^[16]

Characterization of any nanoparticle is crucial in order to determine its stability efficacy and performance. Characterization of silver nanoparticles has been done by various methods which includes X-ray diffraction, Transmission Electron Microscopy, Scanning electron microscopy and UV visible spectroscopy and also energy dispersive spectroscopy. Etc.^[17]

Green synthesis

Green technology works on principle of Green chemistry. It involves use of less toxic material, and eco-friendly techniques. Silver nanoparticles synthesized by using green technology principal then it is called as green synthesis of silver nanoparticles. Green synthesis is now becoming popular because of its various advantages over chemical and physical method. Plant, bacteria and fungi can be used in green synthesis method. Following are few examples of methods of green synthesis, Grape is one of the largest consumed fruits in the world. Grape pomace mainly contains piles seeds and stem. It contains certain biological active compounds. These active components acts as the reducing agents and capping agents as well. This method has its own advantage as green synthesis methods. This may be considered as one-pot synthesis of silver nanoparticles. Nanoparticles formed by this method has face centred cubic crystals of The structures.^[18]

Syzygium cumini which is mainly found in Indian subcontinent and neighbour countries. Aqueous extract of this plant has been used for synthesis of silver nanoparticles. Mainly bark of plant was used. Aqueous extract of bark has been used in the synthesis method. Nanoparticles formed has been evaluated by UV Visible Spectroscopy method and presence of active components by FTIR method of evaluation. Nanoparticles formed by this method show anti bacteria activity against bacillus subtilis and E. coli.^[19]

Pomegranate peels enrich in various bioactive compounds. This ALSO contains compounds which are responsible for the green synthesis of silver nanoparticles. The aqueous extract of this has been used to synthesise silver nanoparticles. Active ingredient in the extract act as

reducing agent for Silver Nitrate to give silver nanoparticles. Size range of nanoparticle was found to be approximately 5 ± 15 NM which was confirmed by TEM studies.^[20]

Coriander leaf extract used to reduce silver nitrate solution to give silver. Act as both reducing as well as capping agent. Means size 11.9 NM of silver nanoparticles was formed which was confirmed by XRD studies. This synthesis has been considered as good example of green synthesis.^[21]

Most of the green synthesis method are cost effective and eco friendly. Various photosynthetic plant has been screened for their activity as a reducing agent. Aqueous extract of these plant was found to be effective in the green synthesis of silver nanoparticles and the nanoparticles so formed has tested as less toxic than any other method.^[22]

Aloe vera is being traditionally used for its anti inflammatory and antibacterial activity. Aqueous extract of aloe vera used for synthesis of silver nanoparticles. The Silver nanoparticle has size range of 36.61 ± 4.88 NM. Which has been studied for its antibacterial activity. Agar well diffusion method was used to carry out the test. Minimum inhibitory concentration was also obtained by the same method and its antibacterial activity was evaluated. ZONE of inhibition for silver nanoparticles was found to be in the of 9 to 18 mm.^[23]

Aloe Vera has many medicinal properties such as antipyretic, antiinflammatory, and antioxidants, also cathartic properties. In another methods, Aqueous extract of Aloe Vera plant yields spherical nanoparticles when allowed to react with silver nitrate solutions. Only spherical nanoparticles were formed. The silver nanoparticles has size range of 15.2 nm.^[24]

Melaleuca leucadendra also known as white paper bark tree which act as both reducing and capping agents. The aqueous extract of this plant was used to green synthesize silver nanoparticles. The method of synthesis was robust and the eco-friendly methods. The synthesis was done at room temperature. The metal precursors was silver nitrate solutions of 0.1 M concentrations. The silver nanoparticles formed by this green synthesis was found to be anticancer and antibacterial in the nature.^[25]

Silver nanoparticles had proven antibacterial and anticancer activity when synthesized by using Allium cepa extract. Then study was done to evaluate it's antidiabetic activity. Green synthesis was found to be less toxic than that of chemical method. Silver nanoparticles

synthesized by this method was evaluated by UV spectroscopy, FTIR ANALYSIS, and Scanning Electron Microscopy Methods. The invitro activity was studied by using alpha amylase and alpha glucosidase enzymes.^[26]

Momordica charantia L. Usually known as bitter melon or bitter gourd or bitter squash belongs to family Cucurbitaceae. This is commonly available medicinal plant. Aqueous extract of this was used to synthesize silver nanoparticles. It is having high nutritional value along with bitter taste. Silver nanoparticles were synthesized using aqueous extract of this plant and fruit extract was generally used. Silver nanoparticles formed were characterized by UV visible spectroscopy, FTIR techniques and Transmission Electron Microscopy Analysis. The green synthesis of silver nanoparticles using this was eco-friendly.^[27]

Seaweeds are natural source of various types of carbohydrates, proteins and fats they are most promising lower group plants with thalus. Silver nanoparticles were synthesized by using aqueous extract of some seaweeds. Sargassum cinctum which is seaweed having potential to synthesize silver nanoparticles was used for synthesis of medicated silver nanoparticles. The photo toxic activity of silver nanoparticles were also studied by seed germination and seed growth. Silver nanoparticles formed by this method was eco-friendly and also cost effective.^[28]

Natural honey Contains various types of vitamins and minerals. It has potential healing properties which includes antibacterial anti-inflammatory and analgesic properties. The use of honey in the synthesis of silver nanoparticles has been reported recently. but the process was observed to be varied accordingly to the source of honey and it's contents. The local honey has been used to synthesize silver nanoparticles acts as a reducing as well as capping agents. Honey has replaced toxic chemical agent i.e. The reducing and capping agents give the eco-friendly aid for the synthesis of silver nanoparticles. Green synthesis of silver nanoparticles by using local honey was reliable and eco-friendly process. It avoids presence of hazardous and toxic solvents and wastes.^[29]

Application

Various applications of green synthesized silver nanoparticles are there in various different fields. Few of them are summarised below.

Textile

Deposition of silver nanoparticles on the surface of textile by Green method shows antifungal properties. Textiles were immersed in Silver Nitrate solution and then natural reducing agent such as extract of *Mikania micrantha* was added. The nanoparticles were formed and deposited on the textile. UV visible spectroscopy and surface morphology study of the textile confirms deposition of the silver nanoparticles. Several Textiles like cotton silk cotton polyester and the fibres shows antifungal activity when attached with the silver nanoparticles.^[30]

Cosmetics

It is found that silver nanoparticles are also showing application in cosmetics.

They are often used according to their particle size and shape in various cosmetic purpose such as anti acne anti dandruff killing agent and curing agents. However toxic effect of silver nanoparticles on the human skins need to be studied thoroughly before using it in the cosmetics formulations which are related to skin and body.^[31]

Agricultural

The agricultural application of silver nanoparticles can be studied by using the sunflower plant exposed to the silver nanoparticles are the Silver ions solutions in the soils.

Silver nanoparticles shows significant effect on plant metabolites. For this sunflower plant is taken as an example. Silver nanoparticles added into soil and get absorbed along with water by sunflower plant shows dramatically increase in enzymes such as CAT SOD GST and GPx. Vitamins like A, E, and C levels also increased. It leads to decrease in levels of water soluble vitamins.^[32]

Green synthesized silver nanoparticles shows various biotechnological applications. This includes antimicrobial activity against wide range of bacteria including Multidrug Resistance Bacteria also. Control over size and shape by using various plants and plant extract gives broad spectrum of activities.^[33]

Green synthesis of silver nanoparticles avoid use of toxic chemicals. Instead of it, plant or plant extracts are used. Thus it can be utilized in food industry also. Antimicrobial property of silver nanoparticle helps to avoid growth of microbes in food. They are applied over food itself or on the food package. Bacterial biofilm formation can be avoided by using silver

nanoparticles antibiofilms. Applying this silver nanoparticles can reduce browning of fruits and its weight loss due to oxidation.^[34]

Multi drug resistance bacteria causing deaths to many patients. Many bacteria species are prone to develop resistance quite easily. Silver nanoparticles along with other antimicrobial agents found to be very effective against MDR bacterial species. Mainly MRSA show high mortality rate and can be inhibited by silver nanoparticles.^[35]

Silver nanoparticles acts as protective aid for food products. Covering packaging material with silver nanoparticles gives protection against growth of bacteria.^[36]

Silver nanoparticle mainly possess antimicrobial property against bacteria such as *E. Coli*, *S. aeruginosa*, *S. aureus*, and *S. pneumonia*. PVP coated silver nanoparticles found to show very potential activity against these bacteria species. Green synthesized silver nanoparticles found to shows broad spectrum of activities.^[37]

Toxicity of Silver nanoparticles

Commercial utility of silver nanoparticles was increased dramatically past few years. Its use on plant and human may lead to toxicity to ecosystem as well. To predict its effect on environment toxicology studies were conducted on plants as well as on animals.

The mechanism of toxicity of silver nanoparticles in plants was not well understood, but the research is now going on to determine it. It will be known soon. Toxicity of silver nanoparticles on plant *Arabidopsis thaliana* was studied. It was observed that silver nanoparticles did not affect seed germination but it showed potential inhibitory effects on the root elongation when compared with silver ions. It was basically a comparative study between silver nanoparticles and silver ions. Accumulation of silver nanoparticles was observed in leaves by scanning electron microscopy. Silver nanoparticles could alter the transcription of antioxidants and aquaporin genes which leads to imbalance between antioxidants and oxygen generating system of plants. It also affects small molecules in plants and the water homeostasis.^[38]

Toxicity of silver nanoparticles was observed in tumor cell. This was performed on two types of cells that are the first one was HeLa (adhesive cells) and the second one is U937 (suspension cells). Green synthesized silver nanoparticles was used for this study. Results

found that silver nanoparticles was toxic to both the cells. Toxicity studies came to conclusion that silver nanoparticles can be used in the treatment of cancers.^[39]

Size of silver nanoparticles play important role in its toxicity. Smaller silver nanoparticles tend to show more toxicity. Some in vitro models were used to determine toxicity of silver nanoparticles in neurons and glial cells. Neurons exposed to silver nanoparticles showed decreased cell viability. In vitro models showed neurotoxic effects of silver nanoparticles in mammals.^[40]

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