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Different method of synthesis and application of Silver nanoparticles – A Review

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Abstract

Silver nanoparticle is an immersing research area because of their valuable characteristics and applications. Silver nanoparticles can be synthesized by using one of the following method: physical method which include- evaporation-condensation and laser ablation method, chemical methods include chemical reduction, Microemulsion, UV initiated photoreduction, Photoinduced or photocatalytic reduction, electrochemical synthetic method, irradiation method, micro assisted synthesis, polymers and polysaccharides and Tollens method, green synthesis of silver nanoparticles are done with bacteria, fungi, algae and plants. Silver nanoparticle are used as: antiviral, antibacterial, antifungal, anti-inflammatory, antimicrobial, anticancer, anti-parasitic and in wound healing, imaging, bone cement, dental materials, catheters, catalytic, and used in air disinfection, surface disinfection and water disinfection.

Keywords: Silver nanoparticles, physical, chemical, green synthesis, antibacterial and wound healing

Introduction

Silver metal discovered and used from last 5000 years for its antibacterial activity. It is immersed as nanoparticle because it shows antibacterial property either by killing or reducing the growth of bacteria without affecting surrounding cells.

Silver nanoparticles are prepared by any one method like physical, chemical and biological. Demand of silver nanoparticle is increasing particularly in medical, pharmaceutical, healthcare, food, consumer, cosmetics stream etc.

Nanotechnology deals with the study of nanoparticles having a size range of 1 – 100 nm. Nanoparticles having tiny size with huge surface to volume and also able to change their physical, chemical and biological properties which make them more valuable for various purpose.

Method of synthesis of silver nanoparticles[3-89]:

As I have already discussed that silver nanoparticles are prepared by three methods which are:

1. Physical method.
2. Chemical method.
3. Biological or green synthesis method.

1.0 Physical method:

1.1 Evaporation – Condensation method:

In evaporation – condensation method the silver nanoparticles are prepared by using a tube furnace at atmospheric pressure. The source material in the furnace is vaporized into a carrier gas. Conventional physical methods for the synthesis of silver nanoparticles include spark discharging and pyrolysis.

Advantages:

- No solvent contamination
- Uniform distribution of nanoparticles

Disadvantages:

- Tube furnace occupies large space
- Consume a great amount of energy
- Require a lot of time to achieve thermal stability

1.2 Laser Ablation Method:

Silver nanoparticles can be prepared by laser ablation of bulk material into solution. The ablation efficiency and the characteristic of silver nanoparticles depend on the following parameters like the wavelength of laser collide the metallic target, the duration of the laser pulses, the laser fluence, the ablation time and the liquid medium with or without surfactant.

2.0 Chemical method:

2.1 Chemical reduction:

The common reducing agent used in the synthesis of silver NPs is either organic or inorganic reducing agents. In aqueous or non-aqueous solution the silver ions are reduced by the chemicals: sodium citrate, ascorbate, sodium borohydride, and elemental hydrogen, NN-Dimethylformamide, and poly ethylene glycol-block copolymers.The above reducing agents reduce the silver ions and lead to the formation of metallic silver, which is followed by agglomeration into oligomeric clusters. These clusters will lead to the formation of metallic colloidal silver particles. Protective agents should be used to stabilize dispersive NPs during the course of metal nanoparticle preparation, and protect the NPs which can be bind onto nanoparticle surfaces and hence avoiding their agglomeration. Thiols, amines, acids, and alcohols are used as surfactant and protect the particles from sedimentation, agglomeration, or losing their surface properties. Polyvinyl alcohol, polyvinylpyrrolidone, polyethylene glycol, poly methacrylic acid, and polymethylmethacrylate reported to be the effective protective agents to stabilize silver nanoparticles.

Kim and colleagues reported that the synthesis of spherical silver NPs with a controllable size and higher monodispersibility using the polyol process and a modified precursor injection technique. In the precursor injection technique, the injection rate and reaction temperature are more important factors for producing uniform-sized silver NPs with a possible their reduced size. By fixing the injection rate at 2.5 ml/s and a reaction temperature to 100 °C, we can get silver nanoparticles having 17 ± 2 nm size. The injection of the precursor solution into a hot solution can be used to induce rapid nucleation in a small period of time and ensuring the production of silver NPs with a smaller size and a narrower size distribution. Chen and coworker have shown the synthesis of monodispersed silver NPs using simple Oleylamine-liquid paraffin system. It was reported that the formation process of these silver NPs can be divided into three steps: growth, incubation and Oatwald ripening stages. Paraffin have higher boiling point (300 ^{0}C) affords a broader range of reaction temperature and hence makes it possible to control the size of silver NPs by varying the heating reaction temperature alone without changing of solvent. The size of the silver NPs could be regulated notonly by changing the heating reaction temperature, or the time of ripening stage, but also by changing the ratio of Oleylamine and silver precursor used.

2.2 Microemulsion techniques:

Microemulsion technique can be used to get uniform and size controllable silver NPs. The silver NPs preparation in two-phase of aqueous and organic phase systems is based on the initial spatial separation of reactants (metal precursor and reducing agent) in two immiscible phases. The quaternary alkyl-ammonium salt mediated the interface between the two liquids and the intensity of inter-phase transport between two phases affect the rate of interactions between metal precursors and reducing agents. Metal clusters formed at the interface are stabilized as surface being coated with stabilizer molecules occurring in the non-polar aqueous medium and transferred to the organic medium by the inter-phase transporter.

2.3 UV-initiated photoreduction:

UVinitiated photoreduction has been reported for synthesis of silver NPs in the presence of citrate, polyvinylpyrrolidone, polyacrylic acid, and collagen.Huang and Yang produced silver NPs through photoreduction of silver nitrate in layered inorganic laponite clay suspensions which act as stabilizing agent to prevent aggregation of silver nanoparticles. The properties of such produced silver NPs were studied as a function of UV irradiation time. Bimodal size distribution and large silver NPs were obtained when irradiated under UV for 3hours. Further irradiation disintegrate the silver NPs into smaller sizes with a single distribution mode until a relatively stable size and size distribution was obtained. Silver NPs preparation by UV irradiation photoreduction technique at room temperature using polyvinyl alcohol as protecting and stabilizing agent have been reported. Concentration of both polyvinyl alcohol and silver nitrate played a significant role in the growth of the nanorods and dendrites. Silver nanoparticles prepared by sonoelectrochemical reduction using a complexingagent, nitrilotriacetate to avoid aggregation has been reported.

2.4 Photoinduced or photocatalytic reduction:

Photoinduced or photocatalytic reduction methods can be used for the synthesis of variety of silver nanoparticles. This is a clean process with high spatial resolution convenience of use and great versatility. Moreover, this process enables one to form the silver NPs in various mediums like cells, emulsion, polymer films, surfactant micelles, glasses etc. Silver nanoparticles with an average size of 8nm were prepared by Photoinduced reduction method by using polystyrene sulfonate/polyallylamine hydrochloride microreactors. It is reported that Photoinduced method can be used for converting the silver nanospheres into triangular silver nanocrystals with required edge lengths in the range of 30-120. Particle growth steps was controlled by using dual-beam illumination of NPs. Citrate and polystyrene sulfonate are used as stabilizing agents. The direct photo-reduction process of silver nitrate was carried out in the presence of sodium citrate by using different light sources like UV, white, blue, cyan, green and orange at room temperature. Sato-Berrú and colleague have proof that this light modification process results in a colloid with different optical properties which may be related to the size and shape of the silver nanoparticles. Ghosh and coworker reported a UV photoactivation method for the formation of stable silver NPs in aqueous Triton X-100. In the above method Triton X-100 molecules act as reducing agent and also as silver nanoparticle stabilizer via template/capping action. Surfactant solution helps to carry out the process of silver nanoparticles growth in the diffusion controlled way by decreasing the diffusion or mass transfer co-efficient. It also helps to improve the silver nanoparticle size distributions by increasing the surface tension at the solvent-nanoparticles interface. Huang and colleague report the synthesis of silver nanoparticles in an alkaline aqueous solution ofAgNO3 and carboxymethylated chitosan by using UV light irradiation. Carboxymethylated chitosan is a water solubleand biocompatible chitosan derivative act simultaneously as a reducing agent for silver cations and a stabilizing agent for the silver nanoparticles. The size range of silver nanoparticles was 2–8 nm, and they can be dispersed stably in the alkaline carboxymethylated chitosan solution for more than 6 months.

2.5 Electrochemical synthetic method

This method can be used to prepare silver nanoparticles. In this method the particle size can be controlled by adjusting electrolysis parameters and to improve homogeneity of silver nanoparticles by altering the composition of electrolytic solutions. Polyphenylpyrrole coated silver nanoparticles within the range of 3-20 nm were synthesized by electrochemical reduction atthe liquid/liquid interface. This nanoparticle was prepared by transferring the silver metal ion from an aqueous phase to organic phase, where it will react with pyrrole monomer. The spherical silver nanoparticles in the range of 10-20 nm along with narrow size distributions were synthesized in an aqueous solution by an electrochemical process. In this method Poly N-vinylpyrrolidone was chosen as thestabilizer for the silver nanoparticles clusters where Poly N-vinylpyrrolidone protects the silver nanoparticles from agglomeration and significantly reduce the silver particles deposition rate and promotes silver nucleation and silver nanoparticle formation rate.

2.6 Irradiation methods

The variety of irradiation methods can be used for the preparation of Silver nanoparticles. Laser irradiation of silver salt aqueous solution and surfactant can produce silver nanoparticles within a well-defined shape and size distribution. Laser can also be used in a photosensitization synthetic method of making silver nanoparticles by using benzophenone. On a short irradiation times low laser powers form silver nanoparticles of about 20 nm while an increased irradiation power form about 5 nm of silver nanoparticles. Laser and mercury lamp can be used as light sources for synthesis of silver nanoparticles.

2.7 Microwave-assisted synthesis:

This is a promising method for synthesis of silver nanoparticles. Microwave heating is better than a conventional oil bath heating when it comes to consistently yielding nanoparticles with smaller sizes, narrower size distributions, and a higher degree of crystallization. Microwave heating required shorter reaction times and hence reduce the energy consumption and give better product yields which prevents the agglomeration of the nanoparticles formed. Carboxymethyl cellulose sodium are used as reducing and stabilizing agent in microwave-assisted synthesis method for the preparation of silver nanoparticles. The size of nanoparticles depends on the concentration of Carboxymethyl cellulose sodium and silver nitrate.The silver nanoparticle prepare by this method is stable for at least 2 months without showing any visible changes. Preparation of silver nanoparticles in the presence of polyvinyl pyrrolidine and ethylene glycol was reported. Microwaves in combination with polyolprocess were used for synthesis of silver nanoparticles by using ethylene glycol as reducing agent and polyN-vinylpyrrolidone as stabilizing Agents. Yin and colleague reported that large-scale and size-controlled silver nanoparticles can rapidly formed under microwave irradiation from an aqueous silver nitrate solution and trisodium citrate in the presence of formaldehyde as a reducing agent.

The use of microwave irradiation to prepare monodispersed silvern anoparticles by using basic amino acids as reducing agents and soluble starch as protecting agent has been reported. Microwave energy and thermal reduction can be combined toprepare silver nanoparticles that can be deposited on oxidized carbon paper electrodes. The silver nanoparticles that are prepared through above method maintain a uniform size between nanoparticles and are well-dispersed over the carbon paper substrate.

2.8 Polymers and polysaccharides:

Silver NPs can prepared by using water as an environmentally friendly solvent and polysaccharides as capping/reducing agents. For synthesis of starch-silver nanoparticles starch is used as capping agent and β-D-glucose as reducing agent. The binding interactions between starch and silver nanoparticles were weak and could be reversible at higher temperatures which allow the separation of the prepared silver nanoparticles. Stable silver nanoparticles (10-34 nm) synthesized by autoclaving a solution of silver nitrate (substrate) and starch (capping/reducing agent) at 15 psi and 121 °C for 5 min have been reported. The silver nanoparticles prepared by above method is stable in solution for three months at about 25 °C. The morphology of silver nanoparticles will change if change the reducing agent or capping agent used in the synthesis of silver nanoparticles.

2.9 Tollens method

This one-step process has been used for synthesis of silver nanoparticles with a controlled size. In the modified Tollens method silver ions are reduced by saccharides in the presence of ammonia, give silver nanoparticle films (50-200 nm), silver hydrosols (20-50 nm) and silver nanoparticles of different shapes. In this method the size and the morphology of silver nanoparticles depends on the concentration of ammonia and nature of the reducing agent. It was confirmed that the smallest nanoparticles were prepared at the lowest ammonia concentration. Glucose and the lowest ammonia concentration (0.005 M) resulted in the smallest average nanoparticle size of 57 nm with an intense maximum of surface Plasmon absorbance at 420 nm. As the concentration of ammonia increases from 0.005 M to 0.2 M the nanoparticle size and polydispersity will increase. When nanoparticle synthesis was carried outat various ammonia concentrations ranging from 0.005-0.20M and pH range from 11.5-13.0 results inaverage particle sizes of 25-450 nm.

3. Green synthesis of silver nanoparticles

The requirement of green synthesis method of silver nanoparticles will become as conventional methods are expensive, toxic and not ecofriendly. So development of a process for synthesis of silver nanoparticles required which will be non-toxic, economic and environment friendly. The green synthesis of silver nanoparticles complies above quality has been developed which does not used toxic chemicals. Some examples of reducing agent used for green synthesis of silver nanoparticle include: Bacteria Yeasts, Fungi, Algae and plants.

Steps involved in the green synthesis of silver nanoparticles:

3.1 Source of Silver ion for green synthesis of silver nanoparticles:

The silver ions are primary requirement for the green synthesis of silver nanoparticles which can be obtained from various water soluble of silver salts. However, most of the researcher used silver nitrate as source of silver ions.

3.2 Biological source of reducing agent for green synthesis of silver nanoparticles:

The silver nanoparticles have been synthesized by using only four kingdom out of five kingdom of living organisms which are Monera (prokaryotic organisms without true nucleus) Protista (unicellular organisms with true nucleus), fungi (eukaryotic, saprophyte/parasite), plantae (eukaryotic, autotrophs) and animalia (eukaryotic, heterotrophs). The data are not available regarding use of animal materials as reducing agent for the synthesis of silver nanoparticles. Due to above limitation, green synthesis of silver nanoparticles has been discussed under headings microorganisms, plants, and bio-polymers. The range of plants used for synthesis of silver nanoparticles algae to angiosperms. However the use of lower plants are limited and mostly used angiosperm plants. Plant partslike leaf, bark, root, and stem have been used for the synthesis of silver nanoparticles. The some common plant used for the synthesis of silver nanoparticles are: *Boerhaaviadiffusa*, *Tinosporacordifolia*, *Aloe vera*, *Terminalia chebulaCatharanthusroseus*, *Ocimumtenuiflorum*, *Azadirachtaindica*,*Emblica officinalis*, *Cocos nucifera*, *Piper nigrum*, *Cinnamon zeylanicum*. *Partheniumhysterophorus*, *Papaversomniferum*, *Menthapiperita*. In most of the silver nanoparticle synthesis, plant extracts played dual role of potential reducing and stabilizing agents with an exception in few cases where external stabilizing chemical agents like sodium-do-decylsulphate were used for stabilization of the silver nanoparticles. Plant extracts contain Metabolites, proteins and chlorophyll are act as capping agents for synthesized silver nanoparticles. The most preferred and convenient solvent for extraction of reducing agents from the plant is water in most of the cases however, there are few reports regarding the use of organic solvents like methanol, ethanol and ethylacetate have been reported. The silver nanoparticles synthesis mainly followed one of the two different routes in one of which utilize extracellular materials secreted in the growth medium whereas in other route directly utilize microbial cell biomass. Silver nanoparticles can be synthesized intracellularly as well as extracellularly by the help of microbes. Few researcher shows interest in the Intracellular synthesis of silver nanoparticles. However, extracellular synthesis of silver nanoparticles has been widely reported. Fusarium is one ofthe commonly used fungal genera for synthesis of silver nanoparticles. In synthesis of most of silver nanoparticles no special capping agent was used for stabilizing the nanoparticles except Perni et al and Shahverdi et alwho used L-cystine and piperitone as stabilizing agents, respectively. Most of the bio-polymers used for the synthesis of silver nanoparticle played the dual role of reducing as well as stabilizing agents with an exception of using starch as a capping agent.

3.3 Separation of green synthesized silver nanoparticles:

The common technique used by the most of the researcher is centrifugation technique to obtain the pellet or powder form of silver nanoparticles. The other technique used rarely by the researcher to separate the silver nanoparticles is the suspensions were dried in oven to obtain the powder form of silver nanoparticles.

Techniques used for determination of silver nanoparticles characteristics include: UV-Vis Spectra, SEM, TEM, FTIR, XRD and EDAX orEDX/EDS. Dynamic Light Scattering (DLS) study is mostly used for silver nanoparticles which are synthesized from bio-polymers. Stability of silver nanoparticles are determined with the help of Zeta potential.The effect of silver nitrate and L-cystine on the organic composition of silver nanoparticles, amount of organic material in silver nanoparticles and thermal stability of silver nanoparticles are determined with the help of Thermo Gravimetric Analysis (TGA). Concentration and conversion of silver nanoparticles is determined by Inductive Coupled Plasma (ICP).

3.4 Monitoring of green synthesized silver nanoparticles:

In most of the research study the change of colorless solution into yellow or slight brownish-yellow or brown color indicate the formation of silver nanoparticles. The significant range of the Surface Plasmon Resonance (SPR) peak for the synthesized silver nanoparticles are 400 - 450 nm in most of the study. The UV-Visible spectral analyses have been used to analyze the dependency of pH, silver ion concentration, extract content on the synthesis of silver nanoparticles and reveal the size-stability of synthesized silver nanoparticles by exhibiting increase in wavelength with increase in size of silver nanoparticles and decrease in wavelength with decrease in size of silver nanoparticles. In most of the research study the SEM morphological analysis revealed that the synthesis of spherical silver nanoparticles except few study shows irregular, triangular, hexagonal, isotropic, polyhedral, flake, flower, pentagonal, anisotropicand rod like structures. The XRD studies in most of the research showed the formation of face centered cubic (FCC) crystalline structured silver nanoparticles except very few research shows cubic and hexagonal structured silver nanoparticles. Elemental composition of silver nanoparticles analyzed with the help of EDS and found characteristic optical absorption band peak around 3 KeV with silver weight percentage ranging from 45% to 80%. The stability of silver nanoparticles has found varied from 1 day to 1 year depending upon use reducing agents and other operating conditions used.

3.5 Mechanism of green synthesis of silver nanoparticles:

Green synthesis of silver nanoparticles by biological entities is due to the presence of large number of organic chemical like carbohydrate, fat, proteins, enzymes & coenzymes, phenols, flavanoids, terpenoids, alkaloids, gum, etc. which are capable of donating the electron for the reduction of Ag+ ions to Ag0. The active ingredient which are responsible for reduction of Ag+ ions are varies depending upon organism/extract used. For nano-transformation of silver nanoparticles, electrons are supposed to be derived from dehydrogenation of acids and alcohols in hydrophytes, keto to enol conversions in mesophytes or both mechanisms in xerophytes plants. In case of green synthesis of silver nanoparticles with microbes the cellular and extracellular oxidoreductase enzymes can perform similar reduction processes.

3.6 Factors that affects green synthesis of silver nanoparticles:

The common physical and chemical parameters that affect the green synthesis of silver nanoparticles include temperature, duration and agitation of reaction silver ion concentration, extract contents, pH of the reaction mixture. Silver ion concentration, extract composition and reaction duration mostly affect the size, shape and morphology of the silver nanoparticles. Most of reported research study shows that the basic medium is more suitable for green synthesis of silver nanoparticles due to better stability of the synthesized silver nanoparticles in basic medium. The other common advantages of basic pH are rapid growth rate, good yield and mono dispersity and improve reduction process. Small and uniform sized silver nanoparticles can be synthesized by increasing pH of the reaction mixture. However, very high pH (more than 11) was associated with the formation of agglomerated and unstable silvernanoparticles. The Reaction parameter like time of stirring and temperature are important parameters in green synthesis of silver nanoparticles. Most of the researcher used temperatures up to 100˚C for green synthesis of silver nanoparticles using bio-polymers and plant extracts, but in case of the use of mesophilic microorganism the reaction temperature should be restricted to 40˚C, because at higher temperatures the mesophilic microorganism dies due to the inactivation of their vital enzymes. When the reaction temperature increase (30˚C - 90˚C) will resulted in increased the rate of green synthesis of silver nanoparticlesand also promoted the synthesis of smaller size of green silver nanoparticles. Research study shows that the size range of silver nanoparticles synthesized from algae, bryophytes, pteridophytes, gymnosperms and bio-polymer sources lie below 50 nm whereas silver nanoparticles synthesized by using angiosperms, algae and bacterial sources are 100 nm or more. In case of green synthesis of silver nanoparticles using microorganisms and bio-polymers the reaction mixture is continuously agitated to protect agglomeration where as in case of plant extracts no need of agitation of reaction mixture.

Applications of Silver nanoparticles[90-129]:

1. Antibacterial/antimicrobial activity:

Silver nanoparticles have been significant used as antibacterial agents for antibiotic resistant bacteria, preventing infections, healing wounds and anti-inflammatory. Silver nanoparticles have a very strong destructive effect on many bacterial species and also have low toxicity towards animal cells. Therefore, silver nanoparticles used as an antibacterial component in the formulation of dental resin composites, bone cement, ion exchange fibers and coatings for medical devices. Silver nanoparticles also shows antimicrobial properties. It was reported that Ag in nanoparticles is considered less toxic than Ag ions. The antimicrobial properties of silver nanoparticles are used in various fields of medication, numerous industries, agriculture, packaging, accessories, cosmetics, health. The antibacterial property of silver nanoparticles against *Staphyloccocus aureus*, *Pseudomonas aeruginosa* and *Escherichia coli* has been investigated. Silver nanoparticles shows the antimicrobial/antibacterial activity by damage the cell membrane permeability, damage the respiration functions of the cell, and reduce the formation of free radicals. When antimicrobial activity of silver nanoparticles was investigated by using fluorescent bacteria, a different conclusion was drawn from the study that silver nanoparticles get attached to the sulfur containing bacterial cell which causes the death of the bacteria. The fluorescent measurements of the cell-free supernatant reflect the effect of silver on recombination of bacteria. Several research studies shows that the when silver nanoparticles are combined with antibiotics they have enhanced the effect of the antibiotics against microorganisms which may be due to the increase in cell wall penetration by antibiotics with the nanoparticles.

2. Antifungal activity:

Silver nanoparticles are found to be prominent against many diseases which are caused by fungi. By inhibiting conidial germination, green synthesized silver nanoparticles showed good antifungal activity against *Bipolaris sorokiniana*. Indoor fungal species such as *Penicillium brevicompactum, Aspergillus fumigatus, Cladosporium cladosporoides, Chaetomium globosum, Stachybotrys chartarum,* and *Mortierella alpine* cultured on agar media are also inhibited by silver nanoparticle.

3. Anti-inflammatory Activity:

Inflammation is the condition in which part of the body becomes swollen, red, hot and sometime painful also and this may occur due to injury or infection. Inflammation give an immunological response against some foreign particles. Silver nanoparticle response to act as anti-inflammatory reagent are limited but they also play important role in this anti-inflammatory field.

4. Antiviral activity:

Viral infections and disease are very common in whole world, so it is very important requirement to make antiviral agents. Silver nanoparticles showing antiviral activity. It has been observed that silver nanoparticles are found to be relatively non-toxic towards humans as well as animals and found to be effective against viruses. Study shows that in case of HIV silver nanoparticles are found to give permissible result. Silver nanoparticles will bind to gp120 and will prevent CD-4 dependent virion binding and infectivity which will result in acting as an effective virucidal agent against cell free virus. Silver nanoparticles inhibit post-entry stages of HIV-1 life cycle.

5. Anti-cancer activity:

Cancer is defined as uncontrolled growth of cells in specific area of the body. Nowadays cancer is so common that every 1 in 3 person in the world is suffering from one or another type of cancer. The therapy for the treatment of cancer include chemotherapy, radiation therapy etc. but the side effects of these treatments are very harsh and the process is also very painful and expensive. So it is most required to find out effective, economic and sensitive molecules for the treatment of cancer.

Many studies have been done to know the favorable result of silver nanoparticles and has found to be most suitable as well as an alternative for other cancer treatments. Silver nanoparticles have ability to target specific cells or tumor at that site only by encapsulation of therapeutic agent. After 6 hours of exposure to *Albizia adianthifolia* leaf extract synthesized silver nanoparticles, A549 cells showed 21% and 73% cell viability and normal peripheral lymphocytes showed 117 and 109 percent viability respectively. This study shows that silver nanoparticles are not harmful to normal peripheral lymphocytes cells. At about 43 g/mL of *Albizia adianthifolia* leaf extract synthesized silver nanoparticles, 50 percent cell inhibition of A549 cells was achieved, and cell death was induced by the generation of ROS, resulting in apoptosis. After 48 hours of Hoechst staining, MCF-7 cells treated with *Sesbania grandiflora* mediated silver nanoparticlesat the dose of 20 g/mL display nuclear condensation, cell shrinkage, and fragmentation. These changes means that DNA repair has been enabled as a result of the cleavage.

6. Anti-parasitic action:

The silver nanoparticles has been reported as larvicidal agents against dengue vector *Aedes aegypt*, *Culex quinquefasciatus*, filariasis vector *C. quinquefasciatus* and malarial vector *A. subpictus*, *Aedesa egypti*, *A. subpictu* and also for other parasites. It is believed that the denaturation of sulfur containing proteins and phosphorus containing DNA by silver nanoparticles will lead to denaturation of organelles and enzymes and hence responsible for the larvicidal activity.

7. Silver nanoparticles in imaging:

Silver nanoparticles possess valuable optical properties that offer a wide range of detection modes such as colorimetric, scattering, Surface Enhanced Raman Spectroscopy (SERS), and Metal Enhanced Fluorescence (MEF) techniques, at extremely low detection limits. Silver nanoparticles scatter light with their extinction spectra contain both absorption and scattering. These silver nanoparticles interact with the oscillating electromagnetic field of light and result in the collective coherent oscillation of the metal conduction electrons with respect to silver nanoparticle positive lattice. This process is resonant at a particular frequency and hence called Localized Surface Plasmon Resonance.

8. Wound healing activity:

Wound healing is a multiple-step process which include integration of activities of many different tissues and cell lineages. Silver nanoparticles have the valuable use in wound healing. Acticoat is the first commercial wound dressing made up of two layers of polyamide ester membranes covered with silver nanoparticles. Silver nanoparticles will promote the healing effect and provide better cosmetic results. Silver nanoparticles help the proliferation and migration of keratinocytes and reduce the formation of collagen by fibroblasts and modulate the number of cytokines produced.The extra-cellularly synthesized silver nanopartilces with fungus *Aspergillus niger* modulate the cytokines involved in wound healing. Silver nanoparticles hydrogel prepared by using *Arnebia nobilis* root extract was examined for wound healing effect in an animal model. The results concluded that silver nanoparticles hydrogel has the positive antimicrobial potential and provided a novel approach for wound treatment.

9. Silver nanoparticles coated catheters:

Due to the antimicrobial activity of silver nanoparticles many research has been conducted to make silver nanoparticles coated catheters. A new generation of silver mold catheters has become available for clinical use. These catheters contain silver nanoparticles which are bonded with an inert ceramic zeolite. Silverline (Spiegelberg GmbH and Co. KG, Hamburg, Germany) and ON-Q Silver Soaker™ (I-Flow Corporation, CA, USA) are two commercially available medical catheters containing silver nanoparticles to prevent catheter-associated infections.

10. Silver nanoparticles in Bone cement:

Poly methyl methacrylate bone cement loaded with 1% silver nanoparticles completely inhibited the growth of *Staphylococcus epidermidis*, *methicillin-resistant S. epidermidis*, and *methicillin-resistant S. Aureus.* There was no major difference between the silver nanoparticles loaded bone cement and the nontoxic control group in quantitative and qualitative cytotoxicity tests. So the use of silver nanoparticles in bone cement is an effective replacement of antibiotics in orthopedic use.

11. Silver nanoparticles in Dental materials:

Research suggests that the effect of silver nanoparticles incorporation to a composite resin at different concentrations have good mechanical properties and valuable antimicrobial activity. Yamamoto et al shows that a resin composite containing silver nanoparticles-implanted filler exhibit a good antimicrobial activity on oral streptococci. Silver nanoparticles in endodontic filling materials provided a valuable improved anti-bactericidal effect against *Streptococcus milleri*, *S. aureus*, and *Enterococcus faecalis.*

12. Silver nanoparticles application in catalytic action:

Silver nanomaterials have applications in automotive catalyst, membranes, fuel cells, photo catalysts, propellants, scratch-resistant coatings, structural ceramics and solar cells. Silver nanoparticles act as effective catalytic medium due to its high surface area and high surface energy. The growing small silver nanoparticles have been proved to be more effective catalysts than stable colloidal particles. These growing nanoparticles catalyzed the borohydride reduction of several organic dyes. As compared with the stable and larger silver nanoparticles, the rate of reduction catalyzed by growing particles was found to be faster. Catalysis is due to efficient particle-mediated electron transfer from the borohydride ion to the dye. The catalytic activity of the nanoparticles depends on their size, $E_{1/2}$ of the dye, and the interaction of dye-particle. By controlling the size of silver nanoparticles their catalytic activity can be controlled because the redox potential depends on the nanoparticle size. Kashayam and Guggulutiktham herbal medicine are used for the determination of the size-dependent catalytic activity of the synthesized silver nanoparticles in the reduction of methylene blue dye by using $NaBH_4$. *Gloriosa superb* induced silver nanoparticles has the electron relay effect which influences the degradation of methylene blue at the end of the 30 min. The catalytic activities of *Dimocarpuslongan* seed extract – silver nanoparticles were assessed against the photocatalytic degradation of methylene blue and chemo-catalytic reduction of 4-nitrophenol (4-NP) to 4-aminophenol (4-AP). The report shows that the prepared silver nanoparticles contain strong chemo-catalytic activity with a complete reduction of 4-NP to 4-AP within 10min. So we can say that the silver nanoparticles contain valuable applications in catalysis.

13. Silver nanoparticles for air disinfection:

Bio-aerosols are the airborne particles of biological origins which include viruses, bacteria, fungi, they are proficient of spreading infectious and allergenic diseases. As per WHO report, 50% of the biological contamination present in indoor air comes from air-handling systems, and the formation of micro-organisms such as bacterial and fungal pathogens was found in air filters. The mycotoxins produce by above pathogens are very dangerous to human health. However silver nanoparticles based air filters has reduced this problem of biological contamination to some extent. Activated carbon filters (ACF) were already examined for the effect of silver nanoparticlesfor the elimination of bacterial contamination. The report shows that the silver nanoparticles based ACF filters are very effective for the removal of bio-aerosols. Jung AH et al generate a new Ag-coated CNT hybrid nanoparticles (Ag/CNTs) using aerosol nebulization and thermal evaporation/ condensation processes and studied their applicability to antimicrobial air filtration. It was found that the antimicrobial filtration efficacy of Ag/CNTs is morethan that of pure Ag-NPs. The polypropylene based air filters were also made with the addition of silver nitrate to use as an antimicrobial agent. The report shows the reduction of biological contamination in air filters. Silver nanoparticles based air filters have better advantage in the removal of biological contamination in the air and the technology behind the antimicrobial filter treatment is very necessary for the future research.

14. Silver nanoparticles in water disinfection:

Water is one of the most important material for the survival of living things on Earth. About 70% of the portion of the earth is covered with water, but only about 0.6 % of total water is suitable for human consumption. Due to above reason safe drinking water is becoming an issue for the entire world. The recent report of WHO shows that at least 1 billion people do not have approach to safe drinking water. Waterborne diseases are the leading cause of death in many developing nations. To reduce the above microbial contamination of water and waterborne diseases there is an enormous need for water treatments methods. A significant interest has arisen for the use of silver nanoparticles for water disinfection. The water filters made up of the silver nanoparticles–porous ceramic composite was tested for their sterilization property. The report shows that at a flow rate of 0.01 liter/min the output count of *E. coli* was nil when the input water had a bacterial load of ~105 CFU/ml. Silver nanoparticles were effectively formed onto the macroporousmethacrylic acid copolymer beads by chemical reduction method for disinfection of water. The silver nanoparticles formed on these copolymer beads were stable during washing with water because of interaction of silver nanoparticles with the –COO− carboxylic functional group on the copolymer beads. The silver nanoparticles were highly effective against all tested bacterial strains of *E. coli, P. aeruginosa, B. subtilis, S. aureus.* Recent research report shows that the colloidal silver nanoparticles has the disinfectant ability for the treatment of gastrointestinal bacterial infections. Chudasama*et al* shows that core-shell magnet nanoparticles comprising with silver nanoparticles are effective disinfectant in water purification system. From the above date we can be said that silver nanoparticles have very much importance in water disinfection and controlling the water pollution to some level.

15. Silver nanoparticles in surface disinfection:

Silver nanoparticles-embedded paints are of particular interest owing to their potential bactericidal activity. The environmentally friendly chemical approach to synthesize silver nanoparticles-embedded paint from common household paint was investigated. The report shows that the surfaces coated with silver-nanoparticle containing paint provide antimicrobial properties against both the gram-positive and gram negative human pathogens like *S. aureus,* and *E. coli.* Silver nanoparticles are also used for the preservation of food material and hence increase their shelf life by avoiding microbial growth. Silver nanoparticles coated paper could be useful for preventing microbial growth for longer periods in food preservation. Gottesman et al described a simple method to develop coating of silver nanoparticles on paper using ultrasonic radiation and this procedure is called the sonochemical coating. From the above study we can say that the silver nanoparticles coated paper has the potential application as packing material in the food industry. Silver nanoparticles can be used in the fabrication of silver nanoparticles impregnated scrub suits worn by healthcare workers. The antimicrobial effect of silver nanoparticles impregnated scrub suits used in a veterinary hospital was investigated by Freeman et al.

Conclusion

Silver nanoparticles is an interested research area because of their unique properties and valuable application in diverse areas such as medicine, catalysis, textile engineering, biotechnology, Nano biotechnology, bioengineering sciences, electronics, optics, and water/ air/ surface disinfection. Silver nanoparticles provide significant inhibitory effects against microbial pathogens and hence widely used as antimicrobial/antibacterial agents ina diverse range of products. Morphology shape, size and size distribution of silver nanoparticles can be controlled by adjusting thereaction conditions such as reducing agent, stabilizer or by employing different synthetic methods. Therefore it is important to elucidatethe effects of reaction conditions onmorphology and size and shape of silver nanoparticles. Silver nanoparticles can be synthesized by using one of the following method: physical method which include- evaporation-condensation and laser ablation method, chemical methods include chemical reduction, Microemulsion, UV initiated photoreduction, Photoinduced or photocatalytic reduction, electrochemical synthetic method, irradiation method, micro assisted synthesis, polymers and polysaccharides and Tollens method, green synthesis of silver nanoparticles are done with bacteria, fungi, algae and plants. Sufficient literature is available on the synthesis of silver nanoparticles through green routes. In green synthesis of silver nanoparticles plants, angiosperm species has been widely used as compared with the other sources. Green synthesis of silver nanoparticles provide environmentally and economically friendly and non-toxic alternatives to chemical and physical approaches. Green synthesized Silver nanoparticle are found to safe and site specific for cancer treatment. Monodispersity, particle sizeand shape and morphology are very important parameters for the evaluation of silver nanoparticles synthesis and hence the efficient control on the morphology, size, shape and Monodispersity of silver nanoparticles must be explored. Various methods has develop to carry out antibacterial study and elucidate their mechanism of anti-microbial/antibacterial activity. Silver nanoparticles are explore in case of cancer therapy as an alternative to other conventional therapies like chemotherapy, radiation therapy etc. As they are used as anti-angiogenic so it is found to be one of the interesting approach for cancer therapy. From the technological point of view the silver nanoparticles Silver nanoparticles are used as: antiviral, antibacterial, antifungal, anti-inflammatory, antimicrobial, anticancer, anti-parasitic and in wound healing, imaging, bone cement, dental materials, catheters, catalytic, and used in air disinfection, surface disinfection and water disinfection. Silver nanoparticles have the ability to degrade textile dyes.

The catalytic activity of silver nanoparticles can be controlled by controlling their size. Silver nanoparticles can be used in advanced portable gadgets and also used in the production of cloths, leather items, and coating because they can protect these items from the attack of various harmful microorganisms.

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