# SYNTHESIS AND ANTIBACTERIAL ACTIVITY OF SILVER NANOPARTICLES: SYSTEMATIC REVIEW

**Pitambri Thakur [1], Jai Kumar [2], Rahul Hakhu[3]**

[1]*Associate Professor, University Institute of biotechnology, Chandigarh University, Gharuan, Punjab, India. E-mail: pitambri.e5316@cumail.in*

[2]*Student, University Institute of biotechnology, Chandigarh University, Gharuan, Punjab, India. E-mail: jai00345@gmail.com*

[3]*Associate Professor, Centre for Distance and Online Education, Chitkara University, Punjab, India. E-mail: drrahulhakhu@gmail.com*

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**Abstract -** Silver is exploited for the benefit of mankind from past centuries. Silver has been proved to be much more powerful when compared to other metallic nanoparticles, not only bactericidal properties but it is also effective against eukaryotic microorganisms and viruses. Creation of Ag Nanoparticles has increased the silver efficacy many folds due to their physical and chemical properties, especially the surface area to volume ratio is most important imparting the antibacterial activity over various microorganisms. To lessen bacterial infections in incurable wounds nanocrystalline silver dressings, creams, gels are formulated. However, several problems are associated with the use. Silver nanoparticle toxicity is a major threat associated with their use and the inhibition of beneficiary microorganisms due to lack of specificity of silver nanoparticles is environmentalist's concern. To reduce the threats associated, there should be a careful assessment of the silver nanoparticles release into the environment and should be regulated. It has to be noted that novel methods to produce silver nanoparticles which reduce the toxicity and other associated threats has to be developed in the future to exploit the vast capabilities of the silver nanoparticles for the benefit of mankind. As technology advancement is always in demand with changing environmental conditions, the present review will focus on the synthesis and antibacterial properties of silver nanoparticles along with its environmental impact.

***Key Words*:** Silver nanoparticles · Antibacterial Activity · Microorganisms · Environmental Impact

## 1. INTRODUCTION

Nanotechnology is the engineering of the operative entities at the molecular scale and encompasses a beyond range of sub-topics but is mainly focused on the manipulation, control, and exploitation of structure ranging in nanometer scale preferably within 100 nm range. Kim Eric Dexler is regarded as the father of nanotechnology and was the first to theorize the field in depth and make it popular. He upon hearing the talk of Richard P. Feynman on the topic "atomic manipulation and nano-factories" got inspired to pursue in the field of nanotechnology. It is a field with applications in science and technology to create products of nanoscale levels. According to Feynmen (1959) (1), "There's plenty of room at the Bottom". Nanotechnology helps us to modify, retain, develop or enhance the metals assets of nanoparticles for a possible role in cell characterization and nano drugs (2). Formation of nanoparticles through the use of nanotechnology has gained a lot of momentum due to various dominions. Metallic nanoparticles display better antibacterial dominion because of larger surface to volume ratio (3). Also, these metallic nanoparticles differ from the bulk metals in their properties due to their minuscule sizes which allow them to be implicated in photoelectronic, catalytic, magnetic sensors and biomedical applications (4-5).

Amongst the metallic nanoparticles silver is widely used due to high thermal and electrical conductivity, higher resistance to oxidation in addition to being sturdy biocide with the ability to be stable at higher temperature along with low volatility unlike iodine (6). From the past 2000 years, the inhibitory and bactericidal silver ions assets are well known and have been researched extensively for the past 6 decades (7). The microbes for example molds, yeast, bacteria, and viruses infect human beings to cause severe diseases which increases the health care costs furthermore, the evolution and rapid development in the manifold antibiotic-resistant or multi-drug resistant (MDR) microorganisms is a major concern. This has led to the development of effective and cost-efficient antimicrobials which can overcome the resistance of this microorganism.

These silver nanoparticles exhibit applications in numerous sectors like food productions, water purification, textiles, and cosmetics. Customer products like dietary supplements clothing, antibacterial sprays, respirators, detergent already utilize the silver nanoparticles in one form or another. These forms of nanomaterials are: metallic silver nanoparticles (8), AgCl particles (9), Ag impregnated zeolite powders (10), dendrimer silver compounds and structures (11), polymer AgNPs composites (12-13), silver-titanium dioxide compounds nanopowders (14). The antibacterial studies can be conducted through a variety of methods such as Kirby-Bauer and Stokes method (Clinical and Laboratory Standards Institute, 2008), Minimum Inhibitory Concentration (MIC), E-test method. However, Clinical and Laboratory Standards Institute has suggested stokes and Kirby-Bauer method since the regulation area of inhibition has been defined for susceptible and resistant values. The risk of developing resistance to silver amongst the microbes is negligible since the metal attacks range of targets in given microorganisms which mean the organism has to develop a range of mutations to acquire the traits of resistance.

## 2. SILVER NANOPARTICLES

Silver a bulk material has various dominions such as ductility, malleability, thermal and electrical conductivity. However, these properties change when the bulk material is shrunk to nanoscale size. The reactivity of nanoparticles increases due to its high surface area to volume ratio imparts physicochemical changes to the nanosized particle made from the same parent bulk material which is more advantageous as compared to larger size particle. According to Ahmad *et al*, (2005) (15) due to the surface area to volume ratio, the classes of metallic NPs include copper, zinc, gold, alginate, and silver etc and have strong bactericidal properties.

However, silver has been proved to be much more powerful when compared to other metallic nanoparticles having not only bactericidal properties but is also effective against eukaryotic micro-organisms and viruses (3). It has been estimated that Ag nanoparticles below the size of 100nm contain around 10,000-15,000 Ag atoms (16). Biological characteristics of Ag nanoparticles show effectiveness against broad spectrum bacteria and resistant strain of bacteria and *Aspergillus*, *Candida* and *Saccharomyces* of fungi (17). It has also been shown that Ag NPs can also be effective to inhibit replication of HIV-1 virus if they of 5-20 nm in diameter according to (18). Bhol *et al*, (2004) (19) suggested that these can effectively abolish tumor necrosis factor (TNF), IL-1b and interleukin (IL)-12 and activate apoptosis of inflammatory cells. Through studies conducted it has been observed silver nanoparticles play role in cytokine modulation and biofilm formation inhibition (20).

## 3. MODE OF ACTION

Silver nanoparticles definite mode of an antibacterial mechanism is not known however, several possibilities have been stated by numerous researchers over the years. Silver nanoparticles show better antibacterial activity due to the increased surface area to volume ratio that provides a larger surface for microbes to make contact with. Several reports in the various literature indicate that electrostatic attraction is one of the factors, the positively charged nanoparticles get attracted towards the negatively charged cells of bacteria, this is a vital interaction (21-22). Mechanisms containing synergy of silver with biomacromolecules have been proposed (23). Several hypotheses have been proposed one being the DNA losing its capacity to duplicate along with the inactivation of cellular proteins upon the treatment with $Ag^+$ since the $Ag^+$ binds to the functional groups present on the protein and denatures it (24). The interaction of $Ag^+$ with nucleic acids and cytoplasmic components interferes the cell membrane permeability by inhibiting the respiratory chain enzymes (25). The collapse of the proton impulsive force resulted by the massive proton flow induced by the addition of low concentration of $Ag^+$ in the species of *Vibrio cholerae* has also been demonstrated (26). The mechanism is not known in detail however, it is stated that $Ag^+$ ions cause $K^+$ ion release (27-29) which affects the cytoplasmic and bacterial membrane. The inhibition resulted in the silver ions being accumulated in the vacuole and in the cell walls in the form of granules (30). Cell division inhibition, destruction to cell envelope and cellular contents (31), increase in the size of the cell and its contents along with structural abnormalities were also observed (32). The possible involvement of free radical has been reported however, the mechanism has yet not been examined (33). Reactive oxidation species, for example, superoxide anion ($O2^{-}$), and hydroxyl radical (OH·) affects the DNA or the mitochondria with subsequent oxidative damage. Sulfur and phosphorous are found predominantly in bacterial cells and are soft bases, nanoparticles react with the soft bases present throughout the cell including in DNA and destroy them causing in cell death. It has also been shown that signal transduction can be modulated by silver nanoparticles by causing dephosphorylation and as we know phosphorylation of protein substrates causes signal transduction thus dephosphorylation has a detrimental effect. Tyrosine residues present in gram-negative bacteria shows the phenomenon of dephosphorylation which causes signal transduction inhibition and (34). Further studies have to be conducted to totally figure out the mechanism of silver nanoparticles and its inhibitory effect on the growth of microbes. Ag NPs have various effects on bacteria which are intricate and complex although direct morphological observation through an electron microscope clearly indicates a structural change in the bacterial cell. Activity of Ag NPs with distinct capping agents and its antimicrobial activity on different Species is given below (Table 1).

**Table -1:** Activity of Ag NPs with distinct capping agents and antimicrobial activity on different Species

| Serial Number | Ag NPs With Capping Agent and Size | Microbes (different species) | Inhibitory Concentration | References |
|---|---|---|---|---|
| 1 | Silver Nanoparticles (12) | *Escherichia coli* | 50-60 $\mu g\ cm^{-3}$ | (34) |
| 2 | Ag NPs (1100) | *Vibrio cholera, Salmonella typhus* and *Pseudomonas aeruginosa* | 75 $\mu g\ mL^{-1}$ | (35) |
| 3 | Various sizes and shapes of Ag NPs | *E. coli* | >100µg for rod-shape NPs | (36-37) |
| 4 | Ag and Au NPs derived from *Candida albicans* cell extract | *Staphylococcus aureus* | 128-512 $\mu g\ mL^{-2}$ | (38) |
| 5 | Ag NPs with PEG, EDTA, PVP | *E. coli* and *Psudomonas* spp. | 3-6 mm (zone of inhibition) | (39) |
| 6 | Ag NPs with PVA-capped | *E. coli* and *Psudomonas* spp. | 0.002% concentration used as hydrogen peroxide sensor. | (39) |
| 7 | Ag NPs with plasma coating | *Staphylococcus aureus* and *E. coli* | 195 nm thickness. | (40) |

## 4. SILVER NANOPARTICLES SYNTHESIS

The enthusiasm in synthesis, characterization and silver nanoparticles application has grown rapidly against a broad spectrum of microorganisms (36, 41) and have a considerably low propensity to activate microbial resistance in comparison to antibiotics (42). For the synthesis of nanoparticles basically, two major paths are followed; these are the top-down and bottom-up approach. Top-down (extreme miniaturization) phenomenon basically means the breaking up of larger amount materials into smaller ones or into fine particles in nanometer size range. Whereas, bottom-up (building blocks) approach involves creating nanoparticles using atoms or molecules.

However, chemical methods and green synthesis are more widely used. The methodology is as follows:

i. **Chemical synthesis:**

The silver nanoparticles prepared through this method are balanced colloidal dispersions in water and prepared by using reducing agents such as $NaBH_4$, $Na_3C_6H_5O_7$, ascorbate or elemental hydrogen. Most frequently this process is employed for the preparation of Ag nanoparticles. In these methods, the (Ag+) is reduced to form colloidal silver. The reduction of the complexes with $Ag^+$ resulted in the formation of silver atoms ($Ag^o$) which then agglomerated into oligomeric clusters; these clusters then give formation of Ag granules (43). These gain yellow color and show a characteristic peak range of 380-400nm wavelength.

ii. **$NaBH_4$ Synthesis:**

$NaBH_4$ act as a reducing agent for the preparation of the spherical silver nanoparticles. And in the existence of $NaBH_4$, the aqueous Ag nitrate gets reduced. $NaBH_4$ in aqueous form having a concentration of 0.002 M was taken in a flask and stirred continuously and cooled for 20 mins. Silver nitrate (0.001M) was added to the reducing agent by maintaining the flow rate of one drop per second with continuous stirring and as the entire 2ml of $AgNO_3$ was added and the stirring was stopped. Ag nanoparticles formed through this method were light sensitive so they were transferred to the dark vessel and were characterized at suitable intervals using various spectroscopic and microscopic methods.

iii. **Sodium Citrate Synthesis:**

Aqueous $AgNO_3$ was reduced by sodium citrate at boiling temperature to form spherical silver nanoparticles. Preparation of silver nanoparticles was done by taking 50 ml of 0.001 M silver nitrate and boiling it. 5ml of 1% $Na_3C_6H_5O_7$ was added and heated with regular stirring, and allowed to continue until the greenish yellow colour solution was obtained thereafter; the solution was cooled (44).

**iv. $NaBH_4$ – PVP Synthesis:**

$NaBH_4$ was freshly prepared to have concentration 50Mm and 0.5ml was taken in the flask which turned the solution colour into light yellow. After the interval of 30seconds add 0.5 ml of PVP (5mg/ml, Mw = 40,000) and allowed reaction to proceed for 30 minutes which turned the solution to darker yellow colour.

**v. Problems associated with chemical methods:**

Borohydride is strong reducing agent and forms minute particles comparatively monodisperse. However; the larger particles formation was effortful to manage due to agglomeration at times. Whereas, weaker reductants like citrates shows slower reduction rate and not uniform. This method is a two-step process, the small Ag particles are produced through the reaction of strong reducing agent in the first step and in the second step these small Ag particles get magnified through the action of the weak reducing agent. The size in primary mark ranges 20-45 nm and increases to 120-170 nm in secondary step (45). The problems associated with the reproducibility of the initial sol and the need for specialized equipment is daunting. Additionally, stabilizers are required to control agglomeration of Ag particles which increases the size of the silver nanoparticles formed through the chemical synthesis. The major disadvantage of using the method is related to environmental toxicity caused by the reducing agents.

**vi. Green Synthesis:**

The chemical methods result in environmental toxicity due to reducing agents therefore; green synthesis is a better option than conventional methods. The green synthesis involves three basic steps which are as follows (1) Solvent medium selection, (2) Benign reducing agent selection (3) Nontoxic substances selection for the Ag nanoparticles stability (46). Green synthesis includes following methods mentioned below:

**a. Polysaccharide method for green synthesis:**

This method uses water and polysaccharides as an environment-friendly solvent and capping agents respectively, under certain conditions polysaccharides can act as solvent as well capping agent. There are different methods to form polysaccharide nanoparticles one such method was by using reducing cum stabilizing agent heparin which is negatively charged with $AgNO_3$ at 70° C for approximately 8 hours. And the resultant nanoparticles were highly stable for 3 months and were without aggregation (47). Other method formed stable AgNPs having size 10-34 nm and was prepared by starch and $AgNO_3$ autoclaving which acted as a reducing agent at 121° C, 15 psi for 5 mins. The resultant nanoparticles formed were stable for 3 months at 25° C.

**b. Tollen's Method:**

This method provides the formation of AgNPs in a single step with control over their size. $Ag(NH3)_2^+$ (aq) (Tollens reagent) gets reduced by an aldehyde Equation (1).

$$Ag\,(NH3)_2{}^{+}{}_{(aq)} + RCHO_{(aq)} \longrightarrow Ag_{(s)} + RCOOH_{(aq)} \quad \text{Eq. (1)}$$

In the modified Tollen's method in the presence of $NH_3$, the $Ag^+$ ions are reduced by saccharides and forms Ag Nanoparticles films (50-200 nm) and Ag hydrosols (20-50 nm) and Ag nanoparticles of discrete shapes and sizes.

**c. Irradiation methods:**

Various types of irradiation procedures are available for silver nanoparticles synthesis, laser irradiation is one such method in which laser irradiation of a surfactant and aqueous silver solution can be done to obtain AgNPs for uniform size and shape dispersal (48). Nanoparticles can be synthesized by addition of a reducing agent as well. The correlation between the laser power and duration on the size of nanoparticles was observed. The lower laser power for short irradiation interval resulted in the Ag nanoparticles synthesis of size ~20 nm and a laser having higher power and longer irradiation time resulted in smaller nanoparticles of size ~5 nm. Mercury lamp can also be used for such photo-sensitization reaction (49).

**d. Polyoxometalates method:**

The potential property of polyoxometalates to synthesize AgNPs is of keen interest since they can be dissolved in water also; and is capable of undergoing stepwise multi $e^-$ reaction without any structural change (50). For synthesis, POM/S/$Ag^+$ (POM: [PW12O40]3−,[SiW12O40]4−; S: propane-2-ol or 2,4-dichlorophenol) was deaerated and illuminated. The POM used serves as a photocatalyst, reducing agent and also stabilizes (51). A salt, $Ag_2SO_4$, and POMs,$(NH_4)_{10}[Mo^V)4(Mo^{VI})_2O_{14}(O_3PCH_2PO_3)_2($$HO_3PCH_2PO_3)2]$-15 $H_2O$ and $H_7[\beta$-$P(Mo^{VI})_4(Mo^{VI})_8O_{40}]$ were reacted together in this reaction POMs serve as both reactants and as a stabilizer. The characteristic SPR band of the silver nanoparticles were obtained at 400 nm after several minutes of mixing without any major effect of the initial concentration of $Ag_2SO_4$ on the location of the band (52). With the diameter of ~38 nm the silver nanoparticles were spherical and were quasi-monodispersed, the particle distribution is displayed in the histogram. It was found that the single silver nanoparticles have an Ag-POM core-shell structure with a ~2nm thick POM layer.

## 5. SILVER NANOPARTICLES TOXICITY AND ITS EFFECTS

Silver nanoparticles properties make them excellent for their use in daily life activities apart from being utilized as anti-bacterial and anti-inflammatory alternatives and in the medical field. However, various independent studies show that nano-silver and silver, in general, might have conflicting effects on human health and the environment. Argyria is a toxicity of silver affecting skin caused when silver is applied to a large wound or in larger quantities as dressings and causes imperishable bluish-grey discoloration or affecting eyes (Agryrosis) and toxic effects like liver and kidney damage; eye, skin irritations may be caused due to exposure to the soluble silver compounds (53). However, no regular reports to silver allergy have been noted as of now. According to Braydich *et al*, (2005) (54) in most of the literature reports silver nanoparticles are benign, hypoallergenic and safe to use but their small size and no form of disposal is considered to be harmful to the ecosystem and environment in general. The major cause of environmental pollution is due to the free silver ions released to the environment through the industrial wastes.

One of the major limitations with silver nanoparticles is that it cannot differentiate between good and bad microbes, therefore; it can inhibit some beneficial microorganism in a particular ecological system (55). Silver nanoparticles caused oxidative stress when low-level exposure was given to rat liver cells and impairs the function of mitochondria (56). Such type of in-vitro silver toxicity assay has been conducted. According to Shin *et al*. (2007) (57) studies also proven that Ag nanoparticles instigate certain toxic effects on the growth kinetics and expression of cytokine of peripheral blood mononuclear cells. Some reports say that male reproductive systems are affected severely by the toxicity of silver nanoparticles since Ag nanoparticles cross the blood-testes barrier and get collected in testes where it can harm the sperm cells. Several studies on the oral toxicity of silver nanoparticles in rats are conducted over the years which indicated that it affects the liver. Kittler *et al.* (2010) (40) noted that aged silver nanoparticles release silver and are more toxic than newly synthesized silver nanoparticles.

As stated, silver nanoparticle's antibacterial activity affects the growth of the good bacteria in the soil, for example, denitrifying bacteria which helps in the process of denitrification which is essential for plants. This process converts the nitrates present in the soil into nitrogen gas required for various plants processes. The disruption of the denitrification has detrimental effects on the plants as well as the environment because it will hamper the plant productivity and cause eutrophication of aquatic ecosystems and destroy its components. Furthermore, the silver nanoparticles also affect the aquatic animals by inhibiting their osmoregulation. The silver ions merge into the gills of the fishes and prohibit basolateral $Na^+$-$K^+$-ATPase activity responsible for the osmoregulation in fishes (58). Daphnia magna 48-h immobilization test was organized to check the potential toxicity of nanosilver on the freshwater environment and the results indicated, according to the Globally Harmonized System of Classification and Labelling of Chemicals silver nanoparticles should be classified under 'category acute 1'. Asghari *et al.* in 2012 (48) recommended that the release of silver nanoparticles into the environment should be carefully studied. Even though silver and nanosilver are toxic to living beings, however, it should be noted that the research conducted in in-vitro studies might differ from in-vivo conditions and the concentrations used for in higher doses. Therefore, more in-vivo studies have to be conducted to come to conclusions about the toxicity of silver nanoparticles.

## 6. APPLICATIONS

According to Jain and Pradeep (2005) (59), silver nanoparticles are used for the filtration of water. Nanoparticles such as Ag-$Fe_3SO_4$ nanoparticles are also used for the water treatment and to prevent the contamination of water magnetic field is used (3). Also, Ag nanoparticles are extensively utilized in medical and biomedical industry for various purposes and in many forms including gels, creams, ointments etc. For example, dressings, creams, gel are formulated with Ag nanocrystals to completely diminish bacteria causing infections in chronic wounds (60). It has also been reported that silver nanoparticles are capable of a healing wound in a better way and have a better cosmetic presence and does not leave any scars when tested on animals (20). Implantable devices, as well as surgical masks, show better antimicrobial efficacy when impregnated with silver (61). Composites derived from inorganic sources can be used as preservatives in various products whereas, a mixture of silica thiosulfate and silica gel microspheres have been utilized for lifelong antimicrobial and antibacterial activity (62). Brief of Silver nanoparticles obtained from different sources and their antimicrobial activities on different microflora is given below in Table 2. Various other uses of silver zeolite are food decontamination and food preservation in the food industry and for the discrete infections treatment (63).

**Table 2:** Brief of silver nanoparticles obtained from different sources and antimicrobial activities on different microflora

| Serial Number | Ag NPs synthesis from different natural sources | Examined Bacterial and Fungal Species | Reference |
|---|---|---|---|
| 1 | *Rosmarinus officinalis* leaf extract | *S. aureus*, *P. aeroginosa*, and *Bacillus subtilis* | (64) |
| 2 | *Ocimumtenuiflorum*, *Solanum tricobatum*, *Centellaasiatica*, *Syzygiumcumini* | *S. aureus*, *P. aeruginosa*, and *Klebsiella pneumonia* | (65-66) |
| 3 | Flower broth of *Tageteserecta* | *Bacills cereus*, *S. aureus*, *P. aeruginosa*, and *Cryptococcaeneoformans* | (67) |
| 4 | Potentilla fulgens | MCF-7 and U-87 cell lines | (68) |
| 5 | Banana peel extract | *B. subtilis* (local isolate), *S. aureus* (ATCC 6538), *P. aeruginosa* (ATCC 9027), *P. aeruginosa* (local isolate), *E. coli* (ATCC 8739)) as well as the yeast *C. albicans* (ATCC 120231) | (69) |
| 6 | *Grewiaflaviscences* | *P. aeruginosa* | (70) |
| 7 | *Eucalyptus camaldulensis* | P. aeruginosa, B. subtilis, and S. aureus | (71-72) |
| 8 | *Papaya* leaf extract | *Micrococcus luteus* MCC 2155, *K. pneumonia* (MCC 2451), *E. coli* (MCC 2412) | (73) |
| 9 | *Aeromonas salmonicida*, *Psychrobacter* sp., *Yersinia kristensenii*, and *P. veronii* | *E. coli* (ATCC 10536), and *S. epidermidis* (ATCC 12128), *K. pneumoniae* (ATCC 29665), | (74-75) |
| 10 | *Mukiamaderaspatana*leaf extract | *K. pneumoniae* (MTCC 3384), *B. subtilis* (MTCC 1790), *Salmonella typhi* (MTCC 3224), and *S. aureus* (ATCC 25923) | (76-78) |
| 11 | *Ginkgo Biloba* leaf extract | *E. coli* and *S. aureus* | (79) |
| 12 | Mycosynthesis | *B. subtilis* and *S. aureus* | (80) |
| 13 | *Azadirachtaindica* and *Ficusbenghalensis* (Bark extract) | *P. aeruginosa*, *E. coli*, *V. cholera*, *B. subtilis* | (76) |
| 14 | *Sesbania grandiflora* leaf extract | Bacteria—*P.* spp., *E. coli*, *S.* spp., and *B.* spp. | (39) |
| 15 | Crude extract of *Bergenia ciliata* | *Micrococcus luteus*, *S. aureus*, *Bordetella bronchiseptica*, and *Enterobactoraerogens* | (81) |
| 16 | *Atrocarpusaltilis* leaf extract | Bacteria—*P. aeruginosa*, *E. coli*, *S. aureus*; Fungus—A. vesicolor | (46) |

## 7. CONCLUSIONS

Creation of Ag Nanoparticles has increased the silver potency many folds due their chemical and physical properties, especially the surface area to volume ratio is a key aspect in imparting the antibacterial activity over various microorganisms. According to few studies silver nanoparticles are used for the filtration of water. Several mechanisms have been developed over the years to elaborate how silver inhibits growth of microbes. However, the exact mechanism is still not known and is under investigation. Over the years several methods for synthesizing nanoparticles have been discovered and implemented such as chemical and biological methods, but due to the problems associated with the chemical synthesis like cost and toxicity of chemicals, biological methods are preferred. For the preparation of nanoparticles, plant extracts are utilized since they are easily available, non-toxic, quickly synthesized and plant sources are diverse. Although Ag nanoparticles have been utilized in different industries like semiconductor, computers etc. the most common use of silver nanoparticles is in the medical sector because of their anti-bacterial and anti-inflammatory properties. Silver nanoparticles are found to be an alternative to develop new and improved antimicrobial agents. Other applications such as the nanocrystalline Ag dressings, gel, creams are formulated to completely diminish bacterial infections in chronic wounds. Although, several problems associated with the use of silver nanoparticles make their use limited.

## 8. FUTURE ASPECTS

Silver nanoparticles certainly stand out in different business applications because of their unique properties. The most noticeable business utilization of silver nanoparticles is in Clinical applications like balms, wraps. Silver nanoparticles can be utilized in the gadgets business for their conductive properties. They can be utilized in beauty care products and individual consideration items like creams, salves, cleansers and different biomedical applications like medication conveyance, imaging, and treatment because of their exceptional physicochemical properties and biocompatibility. Silver nanoparticle toxicity is a major threat associated with their use and the inhibition of beneficiary microorganisms due to lack of specificity of silver nanoparticles is the major concern for the environmentalists. It has to be noted that novel methods to produce silver nanoparticles which reduce the toxicity and other associated threats has to be developed in the future to exploit the vast capabilities of the silver nanoparticles for the benefit of mankind.

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