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GREEN SYNTHESIS OF NANOSILVER PARTICLES FROM PLANTS EXTRACT

Abdul Mueez[1], Shabbir Hussain[2], Muhammad Ahmad[3], Aoun Raza[1], Iffat Ahmed[4], Muhammad Amjad[*1]
[1]Department of Chemistry, Lahore Garrison University, Lahore-Pakistan
[2]Department of Chemistry, Khwaja Fareed University of Engineering and Information Technology, Rahim Yar Khan-Pakistan
[3]Department of Chemistry, DSNT, University of Education, Lahore-Pakistan
[4]Department of Pharmaceutical Sciences, Superior University Lahore-Pakistan

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ABSTRACT

Metal nanoparticles are getting important day by day in various disciplines like in the field of electronics, catalysts, and the field of magnets, mechanics, bio-medical, medicinal cosmetic, bioimaging, materials for fuel cell and photovoltaic cell and in high-speed modern age communication increasing on a regular basis. It is all because of their distinct characteristic physical, biological and chemical properties, which are increasing their popularity every day. This review shows the instant biological synthesis of nanosilver particles by utilizing extracts from different parts the plant such as leaves, roots, flowers, bark and seeds. This review is aimed to provide information about the new innovation regarding synthesis of nanosilver particles through plant mediation and characterization techniques concerned. The cytotoxicity of smaller nanoparticles is greater as compared to the larger ones. In the end, this review concludes with the application of nanosilver particles in various fields and their future. Future prospective and biohazards of nano metals are additionally mentioned.

Keywords: Nanoparticles; Silver nanoparticles; Biosynthesis; Characterization; Applications.

1. INTRODUCTION

Nanoparticles find an important research area in today's science [1-3] due to their broad range of applications in biological [4-7] and nonbiological [8-11] fields. Biosynthesis is defined as the synthesis of Nano-sized particles from biological sources such as microorganisms and plants [12]. Because they are eco-friendly, as these sources are free from hazards linked with other modes of nanoparticle synthesis [13]. Green chemistry principles actually increase safety parameters and improve their efficiency and therefore reduces their toxic influence on society and the environment. Environment-friendly synthesis of nanoparticles (NPs) by biological means encompasses three major areas i.e., eco-friendly usage of solvent, utilization of green reducing agent to reduce ions, and utilization of the substances with no toxicity which performs as stabilizing agents in the synthesis [14]. Biosynthesis of nanosilver particles by the use of plant extracts from various sources has been reported by researchers [15, 16]. During the synthesis of nanoparticles, the extracts of plants work as reducing agents, these extracts of plants contain various kinds of enzymes, vitamins, amino acids, polysaccharides, proteins, polyphenols, etc., which work as reducing agents [17]. For a long, metal silver has been widely used in different biomedical-related products. Silver nanoparticles have gained prominence over other available nanoparticles because of their exciting optical, electromagnetic, catalytic properties and plasmonic activity, and some bactericidal and bacteriostatic effects as well as their antiproliferative actions. Their wide applications in various fields such as photography, catalysis, optics, mirrors, electronics, dentistry clothing and in the foodstuff related packaging industry have increased their own worth in the present market [18].

Noble silver metal has kept its extraordinary dimensional properties in optical and electronic even by going to quantum size which laid its foundation in the field of nanotechnology [19, 20]. Nanoparticle actually means a particulate matter of size 1–100nm [21]. By having a size of nanometers its very advantageous for getting a large surface area to volume ratio for its maximum use [22]. Nanoparticles in solution by having large surface area upon their conformation and their distribution results in their exciting and unique physical and chemical features which are of great use in fields such as antimicrobial development [23], bio-molecular detection, diagnostics [24], micro-electronics components [25] reactional catalysis [26], sensing devices and drugs for cancerous cells [27].

A notable increase in the eco-friendly synthesis of nanosilver particles has made it a major contributor in the field of nanotechnology in which extracts from different parts of plants, fungi and microorganisms are used for the synthesis of nanoparticles as an alternative to conventional physical and chemical modes [28]. Keeping in view the imporance of nanoparticles [29-33], current studies were performed to review the eco-friendly synthesis of nanosilver particles that have many advantages over conventional methods.

Why choose biological synthesis of silver nano particles rather than physical and chemical synthesis?

Methods of biological synthesis have many advantages which include cost- effectiveness, simple and environment friendly. Synthesis of nanoparticles using biological methods by means of micro-organisms [34], biocatalysts [35] and extracts of a plant from its various parts offer a lot of advantages over conventional (chemical and physical) modes of nanoparticle synthesis [36-38].

Due to unfavorable reaction parameters and the intense toxicity of the chemicals by using conventional ways of stable nanoparticles production face challenges of nanoparticle aggregation. Therefore, modern methods which are based on the principle of green chemistry have shown the minimum toxic effects for stable nanoparticle synthesis [39, 40].

Mostly, the conventional method is employed to arrange the nanoparticles of metal. Additionally, the use of chemicals in physical and chemical synthesis modes are typically costly and hazardous while the biogenic ways are inexpensive and shows environmental friendly method for biological synthesis of nanosilver particles from various microorganisms (fungi, yeast and bacterium, etc.) and different parts of the plant such as stem, root, latex, leaves, flower, peel, fruits. Many phytochemicals like polysaccharides, proteins, amino acids, saponins, carboxylic acids, polyphenols, enzymes and amino polyose obtained from plants acting as reducing and capping agents during the synthesis of nanoparticles are mostly employed. The agro-waste and micro-organisms materials are the only cost-effective way for the synthesis of nanoparticles, necessary to minimize the utilization of the harmful chemicals and inspires “green synthesis” of synthesizing nanoparticles practice [41, 42].

This technique is very simple, easy, less energy and time-consuming as compared to other techniques such as physical and chemical methods. Biological methods for the synthesis of nanoparticles have many advantages in terms of resources, time requirement, availability of massive materials, high density, stability and solubility in water [43]. Biogenic synthesis of metal

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nanoparticles provide many opportunities for the consumption of unpreserved waste materials. The use of eco-friendly and economical technologies is increasing day by day has shown a guide to biological synthesis techniques [44]. The chemical synthesis method for the synthesis of nanoparticles produces toxic substances that are absorbed on the surface and cause some serious health diseases. The chemically synthesized nanomaterials have limited applications in the various field of medica [45]. It has been observed that three modes are usually used for the synthesis of silver nanoparticles: plant extracts, fungi and bacteria. The bottom-up technique is used for the biosynthesis of silver nanoparticles in which oxidation and reduction reactions take place. The microbial enzymes or phytochemicals have reducing or antioxidant properties that act on the particular compounds and provide desired nanoparticles. In the synthesis of nanoparticles by biological method mostly three components are involved such as reducing agent, solvent and stabilizing agent. It is necessary during the synthesis of silver nanoparticles that the reducing agents should be environmental-friendly and stabilizing should also be non-toxic. In a brief, it is concluded that the synthesis of silver nanoparticles through biological methods have several advantages ges like fast synthesis, more yields, low cost and environmnet-friendly [46, 47]. Hence, the synthesis of nanoparticles from plant extract is an alternative method for the production of nanoparticles on large scale commercially.

Reason Behind Choosing the Plant Mediated Biosynthesis of Silver Nano Particles

Synthesis of nanoparticles by biological means has gotten superiority by eliminating the complex and time-taking procedures of maintaining cell culture for synthesis [48]. Plant extracts use are very advantageous as they are safe, non-toxic and easily available in our environment and also they are much faster than the microbes in nanoparticle synthesis as they contain numerous metabolites that help in reducing Ag ions. Phytochemicals present in plants are mainly involved in the reduction of silver ions. Flavones, amides, ketones, terpenoids, carboxylic acids and aldehydes are the main phytochemicals involved in the reduction of Ag ions. Moreover, water-soluble phytochemicals i.e., quinones, flavones and organic acids are involved in the quick reduction of Ag ion. Researchers have found that plants of the type x erophytes have biomolecules like anthraquinone and emodin which tautomerizes to form nanoparticles of Ag. While in the mesophytes three kinds of benzoquinones namely remirin, cyperquinone and dietchequinone are found as phytochemicals involved in the reduction. After illustrating all the above studies it is proposed that in the synthesis of Nanosilver particles phytochemicals are directly involved in their reduction [49].

Plant parts, including fruit [50] leaf [51], bark [52], seed [53], peel [54] and root [55] extracts work very well in the biosynthesis of Ag nanopariticles under moderate experimental conditions and replacing hazardous and toxic chemicals by polyphenols, proteins, flavonoids, sugar or saponins or as reducing agents as well as capping agents. Plant mediated green synthesis of Ag nanoparticles is shown in Fig.1

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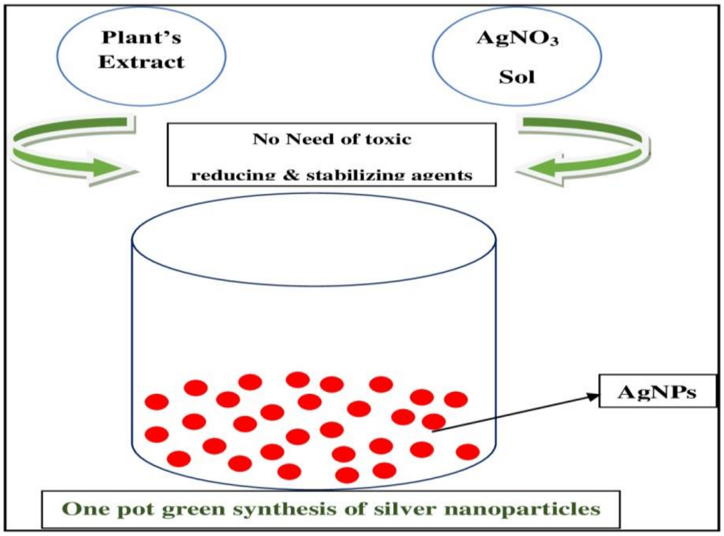

Fig.1: Biosynthesis of Ag nanoparticles by using plant extract

Nanosilver of various sizes have been developed by using plant extracts of Tectona grandis (30–40 nm) [56], Myrmecodia pendans (10–20 nm) [57], and Syzygium cumini (10–15 nm) [58]. Moreover, there are great number of plants has been reported for the synthesis of Nan silver particles few of them are given in Table 1.

Table 1: Plant mediated green synthesis of silver (Ag) nanoparticles

Serial No.	Plants Botanical Name	Nanopaticles size (nm)	References for the given plant
1.	*Abutilon indicum*	106	[59]
2.	*Achyranthus aspera* L.	20-30	[60]
3.	*Acorus calamus*	19	[61]
4.	*Aerva lanata.*	18.62	[62]
5.	*Allium cepa*	33.6	[63]
6.	*Allium sativum* L.	4 .4 ± 1.5	[64]
7.	*Aloe vera*	15.2 ± 4.2	[65]

8.	*Alstonia scholaris*	50	[66]
9.	*Andrographis paniculata* Nees.	28	[67]
10.	*Annona muricata*	20–53	[68]
11.	*Aristolochia indica*	30–55	[69]
12.	*Artocarpus heterophyllus*	10.78	[70]
13.	*Asiatic Pennywort*	18-21	[71]
14.	*Astragalus gummifer* Labill	13.1 ± 1.0	[72]
15.	*Averrhoa carambola*	14	[73]
16.	*Azadirachta indica*	50	[74]
17.	*Calliandra haematocephala*	70	[75]
18.	*Calotropis gigantea*	5–30	[76]
19.	*Calotropis procera*	12.33	[77]
20.	*Capsicum annuum* L.	30-70	[78]
21.	*Carica papaya*	60-80	[79]
22.	*Chenopodium album* L.	12	[80]
23.	*Cinnamomum camphora*	10-20	[81]
24.	*Cinnamon zeylanicum*	50-100	[82]
25.	*Citrullus colocynthis* L.	31	[83]
26.	*Citrus limon*	10-30	[84]
27.	*Clerodendrum serratum*	5–30	[85]
28.	*Cocos nucifera*	22	[86]
29.	*Coleus aromaticus* Lour.	40-50	[87]
30.	*Coriandrum sativum*	26	[88]
31.	*Crataegus douglasii*	29.28	[18]
32.	*Cucumis sativus*	8-10	[89]
33.	*Cucurbita maxima*	19	[61]
34.	*Datura metel* L.	16-40	[90]
35.	*Desmodium triflorum* (L) DC.	5–20	[91]
36.	*Dioscorea bulbifera* L.	8-20	[92]
37.	*Dioscorea oppositifolia* L.	14	[93]
38.	*Emblica officinalis*	10-70	[38]
39.	*Enteromorpha flexuosa*	2–32	[94]
40.	*Eucalyptus chapmaniana*	60	[95]
41.	*Eucalyptus globulus*	1.9–4.3 and 5–25	[96]

42.	*Euphorbia helioscopia*	2–14	[97]
43.	*Euphorbia hirta*	31	[98]
44.	*Excoecaria agallocha*	20	[99]
45.	*Ficus carica*	21	[100]
46.	*Glycyrrhiza Glabra* L.	20	[101]
47.	*Grewia flaviscences*	50–70	[102]
48.	*Helicteres isora*	30–40	[103]
49.	*Hemidesmus indicus*	25.24	[104]
50.	*Hibiscus cannabinus* L.	9	[105]
51.	*Hibiscusrosa sinensis*	14	[106]
52.	*Holarrhena antidysenterica*	2-70	[107]
53.	*Hydrastis canadensis*	111	[108]
54.	*Hydrilla verticilata* (L.f.) Royle.	65.55	[109]
55.	*Hypnea musciformis*	40–65	[110]
56.	*Jatropha curcas*	10-20	[111]
57.	*Justicia adhatoda*	5–50	[112]
58.	*Lantana camara* L.	12.55	[113]
59.	*Leonuri herba* L.	9.9-13.0	[114]
60.	*Lycopersicon esculentum*	10–40	[115]
61.	*Medicago sativa*	2-20	[116]
62.	*Mentha piperita* L.	90	[117]
63.	*Momordica cymbalaria*	15.5	[118]
64.	*Morinda citrifolia*	30–55	[119]
65.	*Morinda pubescens* L.	25-50	[120]
66.	*Morinda tinctoria*	79-96	[121]
67.	*Moringa oleifera*	11	[61]
68.	*Mukia maderaspatana*	13–34	[122]
69.	*Musa balbisiana*	50	[123]
70.	*Myristica fragrans*	7-20	[124]
71.	*Myrmecodia pendan*	10–20	[57]
72.	*Nelumbo nucifera*	16.7	[125]
73.	*Nerium indicum*	29	[98]
74.	*Ocimum sanctum* L.	10	[126]

75.	*Ocimum tenuiflorum*	50	[123]
76.	*Onosma dichroantha*	5–65	[127]
77.	*Paederia foetida* L.	4-15	[128]
78.	*Parthenium hysterophorus* L.	10	[129]
79.	*Pedilanthus tithymaloides* (L) Poit.	15-30	[130]
80.	*Phyllanthus niruri*	30–60	[131]
81.	*Phytolacca decandra*	90.87	[108]
82.	*Piper betle* L.	3-37	[132]
83.	*Piper longum*	46	[133]
84.	*Piper pedicellatum*	5-40	[134]
85.	*Plectranthus barbatus*	20	[135]
86.	*Plukenetia volubilis*	4–25	[51]
87.	*Plumeria rubra* L.	32-220	[136]
88.	*Pongam pinnata L. Pierre*	38	[137]
89.	*Potentilla fulgens*	10–15	[138]
90.	*Prosopis farcta*	10.8	[139]
91.	*Psidium guajava*	26 ± 5	[140]
92.	*Psidium guajava* L.	2–10	[141]
93.	*Quercus brantii*	6	[142]
94.	*Rheum palmatum*	121 ± 2	[143]
95.	*Rosmarinus officinalis*	10–33	[144]
96.	*Saraca indica*	23	[145]
97.	*Saururus chinensis*	38	[146]
98.	*Sesuvium portulacastrum* L.	5-20	[147]
99.	*Sinapis arvensis*	14	[148]
100.	*Solanum trilobatum*	12.50-41.90	[149]
101.	*Solanum xanthocarpum* L.	10	[150]
102.	*Syzygium cumini* L	93	[151]
103.	*Tagetes erecta*	10-90	[152]
104.	*Tephrosia tinctoria*	73	[153]
105.	*Terminalia arjuna*	2–100	[154]
106.	*Thuja occidentalis*	122	[108]
107.	*Trianthema decandra* L.	10-50	[155]

108.	*Turbinaria ornata (Turner)*	20–32	[156]
109.	*Viburnum lantana*	20–80	[157]
110.	*Vitex negundo*	≥20	[158]
111.	*Zingiber officinale* Rosc.	10	[159]
112.	*Ziziphus Jujuba*	20–30	[160]

Reasons to prefer silver nano particles over the other available nanoparticles

The nanoparticles of metals show their physicochemical properties that are entirely different from the bulk compartment [161]. The metal nanoparticles have distinct properties and are mostly used in medical devices, optics, electronics, medication, medical imaging, environment refinement, renewable energies, catalysis, inks and cosmetics [6, 162-166]. Moreover, silver nanoparticles show a wide range of germicidal behavior [167] and used in different fields, such as medical, electrical, food and health, etc. The utilization of metal nanoparticles became remarkably helpful for the broad selection of client commodities, as well as soaps, textiles, food, pastes, and plastics, to boost their market price [168-170].

The Ag-NPs gained remarkable appreciation because of their salient features like antimicrobial, antisepsis activity they are widely used in medicinal applications and to maintain hygiene conditions [171].

The silver nanoparticles possess distinctive physical, chemical and biological properties that are extensively used and considered as most useful as compared to other noble metals due to their physicochemical properties [15] are very small loss of optical frequency in surface-plasmon propagation [172], high electrical, stability and chemically non-toxic as compared to gold and platinum metals that have high- primitive behaviour, high absorption in visible and IR region, surface-enhanced Raman scattering, high catalytic behaviour, chemical stability and nonlinear optical character. In addition, they possess a wide range of antimicrobial activity against microorganisms. Due to the unique properties of silver nanoparticles, many scientists and technologists have a keen interest to develop nano silver-based antiseptic and disinfectant commodities [173].

Among all metal nanoparticles characterized and developed so far, silver nanoparticles have a noteworthy value to their natural properties of showing antimicrobial activity even in their solid-state. Although the importance of silver was known much earlier, it was not well oppressed except for its use in coins and oriental medicine. It has been expected that almost 320 tons of silver nanoparticles are synthesized every year and also used in food products, nonmedical imaging and biosensing [167, 174].

Characterization tools for analysis of silver nanoparticles

UV-visible spectrophotometry

In UV- visible spectra of nanosilver particles, which shows the free movement of electrons as the conduction band and valence band reside very close to each other. Simultaneous oscillation of nanosilver particle electrons in resonance with the incident light causes the surface plasmon resonance (SPR) in it [175-177]. Dielectric medium, shape, morphology, chemical surroundings and size are required for the synthesized nanosilver particles absorption spectra [178-180]. It has been shown in many studies nanoparticles of silver ranging from 2 to 100 nm show the band of absorption at 200 to 800 nm spectral wavelength in UV- visible region.

X-ray diffraction analysis (XRD)

The nanosilver particle's crystalline nature is determined by XRD spectra which shows the particles overall oxidation state as the function of time [181].

Scanning electron microscope (SEM)

Scanning electron microscopy (SEM) is useful in determining the particles of different morphological dimensions of nanoparticles which are synthesized ranging from 10^{-6} to 10^{-9} meters, all because of its surface imaging technology [182-184]. Scanning electron microscopy (SEM) uses an electron beam of high energy which scans the surface of nanosilver particles and the observation of backscattered electrons gives us the characteristic information about the sample of particles [185].

Transmission electron microscope (TEM)

The transmission electron microscopy (TEM) technique is pretty helpful in quantifying and detecting the electronic structure and chemical structure of each and every nanoparticle. TEM shows little superiority over the SEM: because it gives high spatial resolution and also gives some more characteristics dimensions about the nanoparticles [186].

Fourier transforms infrared spectroscopy (FTIR)

Synthesis of metal nanoparticles from bio-molecules involved and their surface chemistry is investigated by Fourier transform infrared (FTIR) spectroscopy [187].

Applications

Nanoparticles of silver are greatly used in the vast technology of nanoparticles. Many of them are used in byproducts for consumers, i.e., water filtration and system of sanitization, soaps, room sprays, socks, deodorants, and food preservation, which ultimately increases the trade sector of nanosilver particles 2[28, 174, 188, 189]. Nanosilver particles and their derivatives show great catalysis activity for the reduction of dye and its removal [190].

Silver NPs have been studied by many scientists who researched their incorporation in most of the substances in order to obtain more advanced characteristics like in solar cells in which NPs of Ag act as plasmonic for trapping of light. So, these unique characteristics are enough to make them useful in many other applications i.e., as a catalyst, components in microelectronics, inks, imaging techniques, health -related products, waste management and medical products [191, 192]. Nanoparticle's actions against different fungi promoted them and become a useful product for various fields of consumer and medical products, including medicine, pastes, soap manufacturing, cosmetics, plastics materials, food stuff, highly sensitive surface-enhanced Raman spectroscopy (SERS) technique application [193-195], textiles and water treatment, etc., that have increased their trade value [196]. Additionally, the nanofibres due to their large surface area found very effective in trapping and attracting small particles. This makes nanofibres useful in filtration as a perfect material [197]. Additionally, nanosilver particles account for quite 23% of obtainable nano-products of the total products in the market. It includes participation from different disciplines of life, i.e., 10.44% cleaning, 52.61% health and fitness, 10.04% food, 2.01% toys, 4.02% medicine, 3.21% electronic machines, 6.02% household equipments, and 11.65% others [198].

Dong and his co-researchers illustrated that nanosilver particles of various dimensions undergo many organic transformations like Diel-Alder reaction, alkylation, Friedel-crafts, cross-coupling reaction, reduction, oxidation, cyclization, and lots of more [199]. Studies of researchers about silver nanoparticles, show exceptional or low selective reactions to highly transformations and selective chemical breakdown for various reactions catalyzed by nanosilver particles. For instance, energetically hard to achieve p-nitrophenol's reduction isn't possible even if we add strong reducing agent sodium borohydride ($NaBH_4$) and require a wait for a month. But, if nanoparticles of silver are allowed to add to the same mixture it can make the impossible reaction possible by producing p-aminophenol [200]. Researchers study, shows that Ag nanoparticles have the great ability of catalysis for the production of pharmaceutical and natural priducts [201].

Biohazards

Nanoparticles show relatively more toxicity as compared to macroparticles. They're cytotoxic to cells, organelles and also show toxicity to biological molecules [202]. At the cellular level on exposure to nanoparitcles shows oxidative stress and severe peroxidation of lipids. [203]. Reactive oxygen species are known to be the cause to produce cytotoxicity by silver nanoparticles through which reduction in the level of glutathione and increase in the level of reactive oxygen species.

Researchers have reported that surprisingly nanosilver particles cannot differentiate between bacteria of different strains and therefore kills even those microorganisms that are beneficial to different life forms [204]. Only a few studies are conducted to check the toxicity of nanosilver particles. According to one study in vitro on rats, showing that even a small amount of silvernanoparticles exposure resulted in the reduced rate of mitochondrial function linked to increased oxidative stress which ultimately creates toxicity [205]. The same results happened in mouse germline according to another study. According to researcher silver, NPs have also known to be toxic in vitro mouse germline cells as they also reduced the mitochondrial functioning which results in leakage through the cell membranes. Aggregates of nanosilver particles have shown to be more toxic to cells than asbestos [206]. Researchers have provided an information that shows silver ions causing changes in potassium and sodium ions permeability to the cell membrane at concentrations that don't even limit ATP, potassium, sodium, or mitochondrial activity [207]. Few studies have depicted that nanosilver can activate many toxic effects on the proliferation and cytokine expression by peripheral blood mononuclear cells [208]. Another biohazard of nanosilver is on the male genital system which shows its potentially toxic effect. A few type of researches indicate that silver NPs by crossing the barrier of blood-testes and can deposit inside the testicles where sperm cells got affected badly. [209].

It is observed that silver-based dressings available in the market also possess cytotoxic effects [210]. The oral toxicity of nanosilver on rats's liver in vivo conditions has been seen in a research work. In the histopathological study, it has been observed that there is more occurrence of CBD hyperplasia, with or without fibrosis and necrosis during the animal study [211]. Research also proved that by storage of nanoparticles over a period of a long time there is the

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release of silver. Therefore, it is concluded that the old nanosilver is more dangerous and hazardous than the new nanosilver particles [212].

A few properties of nanosilver are responsible for its cytotoxicity that include particle size, agglomeration and sedimentation. It has been confirmed that the silver nanoparticles of 10 nm coated with polyvinyl povidone (PVP) and citrate are toxic to the cells of human lungs [213] as exposed for 24 hours. Although, the AB test used to measure cell proliferation and mitochondrial activity. On the other hand, the LDH test is used to confirm the cytotoxicity of silver nanoparticles during membrane damage from the cytoplasm [214, 215]. It has been shown that cytotoxicity is associated with enzyme inhibition that is due to the discharge of silver ions because they prevent the catalytic activity of lactate dehydrogenase (LDH).

During the study, it has been observed that DNA was damaged by silver nanoparticles but they did not increase reactive oxygen species (ROS) when cells were exposed to them for 24 hours at a dose of 20 µg/mL [214]. It has also been suggested that silver ions released from AgCl within the biological fluid and complexed [213]. The AgCl formation is feasible as long as the fluid is loaded with Cl^- ions yet it can not dissociate to Ag^+ and Cl^- ions because AgCl is insoluble in aqueous an medium [216]. Further, extracellularly released silver ions in the cell medium did not show toxicity, perhaps it might react with Cl^- ions to produce insoluble AgCl.

Carlson revealed that the 15 nm hydrocarbon coating of silver nanoparticles increased in reactive oxygen species (ROS) [217]. Liu has reported that 5 nm silver nanoparticles were more toxic than 20 and 50 nanoparticles to four cell lines are HePG2, MCF-7, SGC-7901 and A 549 [217]. Wang demonstrated that smaller nanoparticles (10-20nm) cause more cytotoxicity than larger ones (110nm), and citrated coated silver nanoparticles produce severe neutrophilic inflammation in the lungs of mice as compared to those with larger ones [218], also cell feasibility and DNA break can be confirmed by ROS generation [219], which might look contradictory to reports by others researchers in vitro studies [220].

It is assumed that DNA rupturing is because of the disruption of silver nanoparticles with repair pathways in vitro study of DNA, once DNA is damaged then can not be recovered again. As we know the living cells are capable to repair and proliferate. Generally, we can understand that both the nanoparticles of silver and its ions existing at the subcellular levels. The change of silver to Ag+ ions occurs inside the cell membrane because of various biological processes. The elemental Ag discharge is directly related to the dimensions of nanoparticles [221]. In another research, it is reported that the dimensions dependent toxicity are said to be because of the intracellular release of silver ions. Another observation regarding silver nanoparticles is that the antibacterial effect was restricted under anaerobic conditions reason being the oxidation reaction i.e., silver to Ag plus ions conversion stops under anaerobic conditions . Silver NPs have great action against the P. vulgaris, Y. enterocolitica, E. coli, S. faecalis and S. aureus. As nanoparticles are smaller in dimensions than the bacterial cell they stick with cell walls resulting in a hindered flow of nutrients across the membrane causing microbial death [222]. So, it is deduced that greater concentration around the cell wall ceases the cellular division of microorganisms.

Researchers investigated that nanosilver due to its antimicrobial activity, can adversely influence soil friendly bacteria that exhibit toxic effects on denitrifying bacteria, silver can disturb the denitrification process in which the conversion of nitrates into nitrogen gas takes place. The environmental denitrification disruption occurs by the reduction of plant growth that finally causes eutrophication of marine ecosystem, lakes rivers and ecosystem is also destroyed [223]. The silver ions also affect aquatic animals and, in particular interact with the gills of fish and show Na+-K+-ATPase activity, which can inhibit osmoregulation within the fish [224]. Daphnia Magna 48-h immobilization test was conducted to check the toxic effect of silver nanoparticles in freshwater test thus the silver nanoparticles are classified under category acute 1 as per Globally Harmonized System of Classification and Labelling of Chemicals [225]. In vivo and vitro conditions it has been observed that the silver nanoparticles can cause toxicity to live organisms. Therefore more studies especially in vitro need to be done before declaring nanosilver particles as hazardous ones.

It is also noticed that the combination of silver nanoparticles with antibiotics reduce the toxicity to human cells by reducing the specified quantity [226]. Silver nanoparticles show antimicrobial behaviour against microorganisms either alone or in combination and also effective for killing resistant bacteria [227]. It is seen through experiment E.coli shows resistant against silver nanoparticles on its regular exposure for 225 generations through genetic change [228]. So, it is necessaryt to take preventive measures in order to keep away from the risk of continued exposure to microbes. Further, it is also observed the silver nanoparticles produced from bacterial species show cytotoxicity to cancer cells. The cell ability to function is reduced during a dose-depenendent mode in a mode in HeLa cancer of cervics [229], A549 adenocarcinoma (malignant tumor) cancer of lungs [230], MDA-MB-231 cancer of breast [231] and HEP2 [232] cell lines. In many studies, it has been noticed that silver nanoparticles are harmful for nitrogen fixation [233]. Excessive reactive oxygen species like hydroxyl (·OH), superoxide (O2-), peroxy (RCOO·) and hydrogen peroxide (H2O2) can damage the cellular protein and are considered a carcinogen. The reactive nitrogen species as nitric oxide (NO·) and nitrogen dioxide (NO2-) [234, 235]. The environment which is contaminated with ROS may stop cell replication and development. However, the presence of an antioxidant like an enzyme or a non-enzymatic component that scavenges the free radicals can delay the cell-damaging process [236].

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CONCLUSION

The above review covers a comparison between the different modes of Ag nanoparticles synthesis and its great number of applications. This review highlights the evolving area in the discipline of nanoscience and the researcher's hard work on plant-mediated biosynthesis of Ag NPs. It explores the benefits for future researchers due to its gradual increase in the field of publications. This paper contains new ideas for pharmacists due to its great number of applications in the field like larvicides, anticancer drugs, biological tools and devices that contain these exciting Nanosilver particles. Hence, nanoparticle synthesis biologically has played a significant role in the field bionanomedicine and its dominance has also been acknowledged by other fields. Although, the persistency of nanoparticles is confirmed their effect on human body health and food products through clothes, paints, medicines etc. are not clear yet but they might reach through sewage and sludge to our crops. In spite of its great number of advantages there

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few disadvantages of using nanoparticles of Ag. Researchers showed that they reduce the nitrifying bacteria's growth and ultimately reduces the removal of biological nitrogen from the sources and for this little amount of Ag NPs is enough. There are studies that prove that Nano silver particles can cause serious damage to the ecosystem if they are allowed to release freely in the natural environment. So, this review is concluded with that precautionary measurements must be taken in order to avail the benefits from these exciting nanoparticles by spreading awareness among the people for its level of safe usage, by keeping the limits of its utilization in mind and ultimately all these things will help us to eliminate its hazardous effects from the environment.

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