Silver Nanoparticle Antiviral Property Over Masks And Other Clothing For Healthcare worker's.

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Abstract: Nanoparticles is the emerging technique in current era and thus the following review paper present the synthesis of silver nanoparticles and application towards its uses as antiviral activity. The silver nanoparticles have diverted the mass attention of the scientific community and medical professionals due to their wide range of application in the biomedical fields. It especially has effective use against the microbes and infectious agents. An antiviral Nano-coatings developed by Professor Ashwini Kumar Agrawal of Indian Institute of Technology, Delhi has been approved by the Department of Science and Technology (DST), India for producing anti-COVID-19 Triple Layer Medical masks. As Silver is known to have strong antimicrobial activity against bacteria, viruses, fungus, and so on it can be used for producing these triple layer masks. In this review paper the various techniques are explained for the preparation of silver nanoparticles. Along with its importance, applications in the medical field and also can be used as antiviral agents in the preparation of masks, sanitizers, etc.

IndexTerms - nanoparticle, silver, biomedical,microbes,antiviral properties,coronavirus,COVID-19,precaution,medical applications

I. INTRODUCTION:

Over the last few decades, the development of microbicidal coatings has received a great deal of attention because of their distinctive physicochemical and biological properties. Impregnating, adsorbing, or covalently attaching microbicidal agents to the object are some methods by which the microbicidal coating can be prepared. In current period of time, the production of auto-sanitizing products for healthcare is highly recommended. Silver is known to have strong antimicrobial activity against bacteria, viruses, fungus, and it has been used as an antimicrobial agent for centuries. For example; the Phoenicians used silver vessels to preserve water and wine during their long voyages and also the ancient Egyptians believed that silver powder provided beneficial healing and anti-disease properties, thus silver compounds were used for prohibiting wound infection prior to antibiotics. Here comes the reason why silver nanoparticles have received a great deal of attention. Silver nanoparticles can be used in many different products because of their exceptionally small size and their potential antimicrobial effect. At the present time silver nanoparticles have attracted increased interest and are currently used in various industries including medicine, cosmetics, textiles, electronics, and pharmaceuticals. In the development of nanoparticles for mediated therapy, some laboratories have used a variety of cell lines under in vitro conditions to evaluate the properties, mode of action, differential responses, and mechanisms of action of silver nanoparticles. [1,2 ,3]

II. CORONA:

In late December 2019, several patients from Wuhan, China were admitted to hospitals with symptoms of pneumonia. As the number of patients presenting with similar symptoms started to rise, the causative agent was eventually isolated from samples. It was initially called the 2019 novel coronavirus (2019-nCoV) and has been recently relabeled as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2); the disease had been named coronavirus disease 2019 (COVID-19).

Over the next few weeks, the virus spread from Wuhan to affect different provinces in China and, after a few months, it is now present across the globe. As of May 3, 2020, there have been 3,558,840 confirmed cases globally, and 247,970 deaths have been registered. The World Health Organization (WHO) called COVID-19 a pandemic on March 11, 2020.

2.1 Coronavirus Genetics:

Coronavirus, so named because they look like halos (known as coronas) when viewed under the electron microscope, are a large family of RNA viruses. The typical generic coronavirus genome is a single strand of RNA, 32 kilobases long, and is the largest known RNA virus genome. Coronaviruses have the highest known frequency of recombination of any positive-strand RNA virus, promiscuously combining genetic information from different sources when a host is infected with multiple coronaviruses. In other words, these viruses mutate and change at a high rate, which can create havoc for both diagnostic detection as well as therapy (and vaccine) regimens.

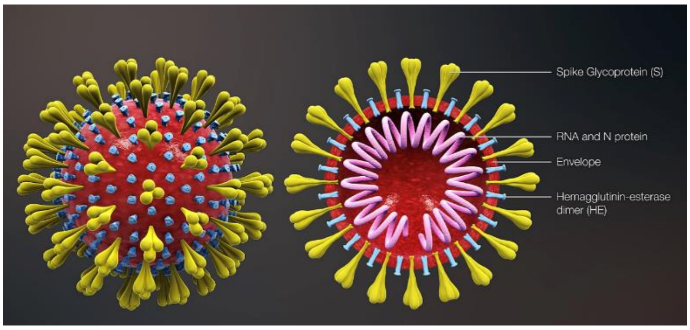

Fig 1: Diagram of coronavirus virion structure showing spikes that form a "crown" like the solar corona, hence the name.

Coronaviruses have an unusual replication process, which involves a 2-step replication mechanism. Many RNA virus genomes contain a single open reading frame (ORF) which is then translated as a single polyprotein that is then catalytically cleaved into smaller functional viral proteins, but coronaviruses can contain up to 10 separate ORFs.

table 1: symptoms of coronavirus disease

Symptom	Range
Fever	83-99%
Cough	59-82%
Loss of appetite	40-84%
Fatigue	44-70%
Shortness of breath	31-40%
Coughing up sputum	28-33%
Muscle aches and pains	11-35%

III. WHAT ARE SILVER NANOPARTICLES:

Silver (Ag) nanoparticles are nano sized particles of elemental silver, of size less than 100 nanometers. Silver Nanoparticles have been synthesized in various shapes and sizes like spherical, triangular, Nano-rods, prisms, Nano-wires, etc. and sizes ranging from 1 nm to 100 nm.

IV. SYNTHESIS OF SILVER NANOPARTICLES:

There are various physical, chemical and biological synthetic methods have been developed by which silver nanoparticles can be obtained of different shapes and sizes.

4.1 Physical approaches:

4.1.1 Evaporation-Condensation: In this method Vaporize the material into gas, and then cool the gas.[41,42,43]

(a) Using a tube furnace has some disadvantages:

The tube furnace consumes a great amount of energy which raises the environmental temperature around the source material and it requires power consumption of more than several kilowatts. Requires a preheating time of several tens of minutes to reach a stable operating temperature.

(b) Using a small ceramic heater with a local heating source

The evaporated vapour can cool faster than tube furnace. This physical method can be used for:

1. Formulation of small nanoparticles in high concentration.
2. Formation of nanoparticles for long-term experiments for inhalation toxicity studies.

4.1.2 Laser ablation: Laser ablation of metallic bulk materials in solution. Laser ablation can vaporize materials that cannot readily be evaporated. The produced silver nanoparticles depend upon[44]:

1. Wavelength of the laser.
2. The duration of the laser pulses.
3. The ablation time duration.
4. The liquid medium.
5. The presence of surfactant.

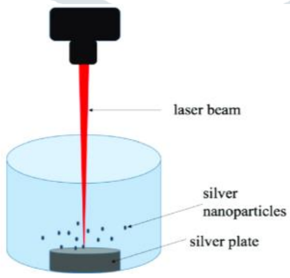

fig 2: laser ablation in liquid medium

4.2 Chemical approaches:

The most common approach for synthesis of silver nanoparticles is chemical reduction. In general, different reducing agents such as; Sodium citrate, Ascorbate, Sodium borohydride($NaBh_4$), Elemental hydrogen etc. The reducing agents reduce silver ions and lead to the formation of metallic silver, which is followed by agglomeration into clusters. These clusters eventually lead to formation of metallic colloidal silver particle.

It is important to use protective agents to stabilize dispersive nanoparticles during the course of metal nanoparticle preparation, and protect the nanoparticles, avoiding their agglomeration.

Some chemical methods for the synthesis of Ag NPs include chemical reduction, electrochemical synthesis, the irradiation-assisted method, and the pyrolysis method, as summarized in Table 1.

table 2: chemical method for preparation of silver nanoparticle

Method	Size (nm)	Note
Chemical reduction	<50	Hydrogen peroxide was used as reducing agent.[25]
Chemical reduction	7.6-13.11	Sodium borohydride was used as reducing agent.[26]
Chemical reduction	7, 29, 89	Gallic acid was used as reducing agent.[27]
Chemical reduction	<30	Sodium citrate was used as reducing agent.[28]
Chemical reduction	5, 7, 10, 15, 20, 30, 50, 63, 85, 100	Sodium borohydride and trisodium citrate were used as reducing agent.[29]
Chemical reduction	9, 11, 24, 30	Hydrazine hydrate and sodium citrate were used as reducing agent.[30]
Chemical reduction	~5	Sodium borohydride and citrate were used as reducing agent.[31]
Electrochemical synthesis	4.8	Dry oxygen-free solvents were used under an argon atmosphere.[32]
Electrochemical synthesis	1-18	The film, as a cathode, was ion exchanged to desired Ag contents in AgNO3 solutions and then reduced electrochemically.[33]
Electrochemical synthesis	30, 46	A platinum was employed as cathode and anode.[34]
Irradiationassisted method	30-120	Dual-beam illumination system (546 nm/440 nm) was used.[35]
Irradiationassisted method	2-8	Ag NPs were synthesized with UV (266 nm) irradiation.[36]
Irradiationassisted method	50	Ag NPs were synthesized by a microwave irradiation (Cu-Kα; 0.154 nm at 40 kV).[37]
Irradiationassisted method	3-30	Ag NPs containg hydrogels were prepared by radiation crosslinking and reduction, simultaneously.[38]
Pyrolysis method	20-300	An argon gas was used under oxygen-free environment.[39]
Pyrolysis method	3-150	All solutions were dispersed by oxygen environment.[40]

4.3 Biological approaches:

Biological approaches or in other term it can also be called as the green synthesis method. It is based on green chemistry programs which is known as the representative environment-friendly synthesis method. Some biological materials using green synthesis methods using bacteria, fungi, and plant are shown in Table 2.[24]

table 3: biological method for preparation of silver nanoparticle

Material	Size (nm)	Note
Bacteria	28-122	E. coli.[4]
Bacteria	10-15	Rhodococcus spp.[5]
Bacteria	44-143	Bacillus thuringiensis.[6]
Bacteria	38-85	Ochrobactrum anhtropi.[7]
Bacteria	8.1-91	Pantoea ananatis.[8]
Bacteria	41-68	Bacillus brevis.[9]
Bacteria	105	Bacillus mojavensis.[10]
Fungi	1-20	Aspergillus terreus[11]
Fungi	8-50	Pleurotus ostreatus.[12]
Fungi	25-50	Bryophilous rhizoctoni.[13]

	10,50	Penicillium fellutanum.[14]
	7	Biomass derived from Aspergillus flavus.[15]
	14,25	Penicillium expansum.[16]
Plant	9	Jasminum nervosum.[17]
	10-40	Artemisia princeps.[18]
	20	Cassia auriculata.[19]
	34	Eclipta prostrate[20]
	20, 30	Coffea arabica.[21]
	10-60	Antigonon leptopus.[22]
	25-40	Fraxinus excelsior.[23]

V. APPLICATIONS FOR HEALTHCARE WORKERS (HCWS):

"Emerging" infectious diseases (EIDs) can be defined as infections that have newly appeared in a population or have existed but are rapidly increasing in incidence or geographic range. Among recent examples are Ebola Virus Disease (EVD), Middle East Respiratory Syndrome coronavirus (MERS-CoV), Severe Acute Respiratory Syndrome (SARS), infection with MRSA, and Cholera. The HCWs involved during medical treatment of EID patients have a fatal risk of contact infection. As described, Ag NPs have a strong microbicidal activity with a broad spectrum. Furthermore, the mechanism that has been proposed is that Ag NPs yield ROS (reactive oxygen species), leading to oxidative stress in addition to the generation of free silver ions. Therefore, Ag NPs will provide useful materials to protect HCWs from the risk of contact infection. To prevent contact infection, HCWs usually wear protective clothing. Pathogenic microbes, which are mainly generated by patients, stay alive on the surfaces of protective clothing. There is a risk of infection by incorrect contact when removing the clothing, to overcome that problem, it is necessary to develop an evidence-based protective clothing for HCWs with the aim of developing a new microbicidal/antiviral material, using Ag NPs absorbed on a chitin sheet with a nanoscale fiber-like surface structure.

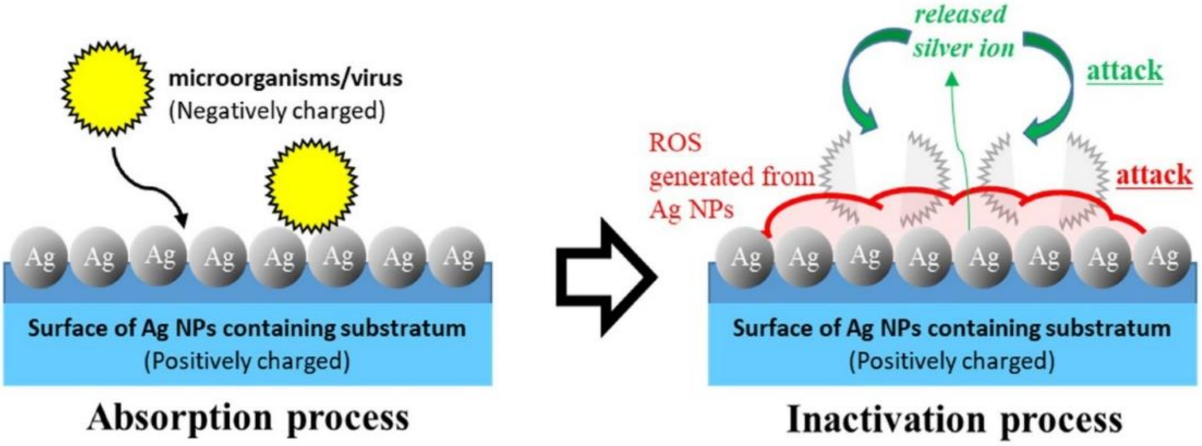

fig 3: The mechanism for microbicidal and antivirus activities of the Ag NP chitin nanofiber sheet (CNFS). To prevent contact infection of healthcare workers (HCWs), an Ag NP chitin nanofiber sheet (CNFS) was developed, showing strong microbicidal activity against microorganisms/viruses via reactive oxygen species (ROS) and silver ions on the surface of substratum.

VI. ANTIVIRAL ACTIVITY OF SILVER NANOPARTICLES:

Ag NPs are famous for their antimicrobial activities; therefore, researchers have started evaluating the importance of Ag NPs in controlling infectious diseases caused by pathogens and viruses. However, the number of reported works using Ag NPs for controlling viral infections is very low but still it can pave the way for other researchers to show their interest in dealing against viral infections using nanoparticle specifically Ag NPs. Elechiguerra et al. published their study conducted for assessing the effect of Ag NPs on the HIV-1 virus. The authors concluded and revealed that the interaction between Ag NPs and virus is size dependent (small sized nanoparticles are more effective against these viruses). They further enlightened the idea that Ag NPs get adhered to the sulphur present in the gp120 glycoprotein knobs that results in hampering the normal activities of the virus therefore hindered the normal functions of the virus. This mechanism was second by another group of researchers when they published their report after assessing the role of Ag NPs on HIV virus. According to their published article they proposed that Ag NPs were effective against HIV virus having the capability to bind to the sulphur present at gp120 glycoprotein knobs thus ultimately retarding their normal functions and binding to the hosts.[45,45]

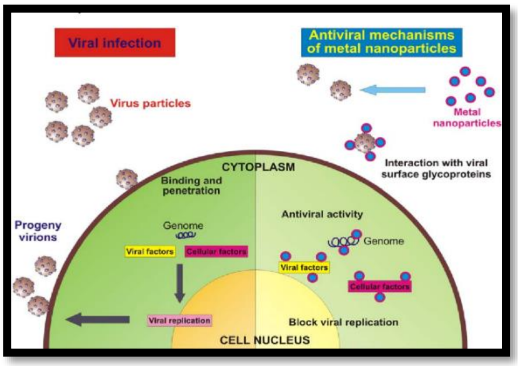

fig 4: Antiviral mechanism of silver nanoparticle over a living cell

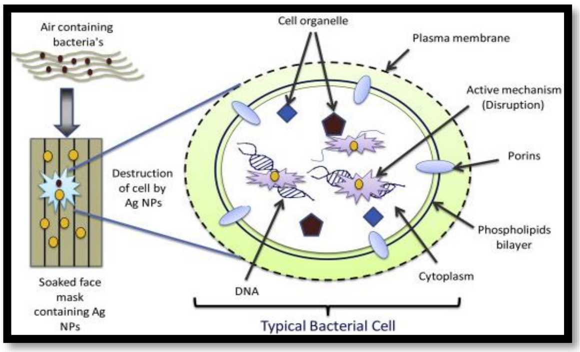

fig 5: Enhanced anti-microbial response of commercially face mask using colloidal silver nanoparticle

VII. CONCLUSION:

During this uplifting pandemic of coronavirus in various countries, the clothing used by healthcare workers are not completely immune to microbes as it still retains on the surface of equipment and fiber. Using Ag NPs can improve the safety for healthcare workers by its automatic sanitizing properties. This review comprehensively addressed the preventive measures, which can be used to prevent contact infection from various infectious microbes. Due to the microbicidal/antiviral properties of silver nanoparticle, production of various medicinal products and clothing can be achieved.

REFERENCES

1. Ashkarran AA, Ghavami M, Aghaverdi H, Stroeve P, Mahmoudi M (2012) Bacterial effects and protein corona evaluations: crucial ignored factors in the prediction of bio-efficacy of various forms of silver nanoparticles. Chem Res Toxicol 25:1231–1242
2. Lem KW, Choudhury A, Lakhani AA, Kuyate P, Haw JR, Lee DS, Iqbal Z, Brumlik CJ (2012) Use of nanosilver in consumer products. Rec Pat Nanotec 6:60–72
3. Faria AF, Martinez DST, Meira SMM, Moraes ACM, Brandelli A, Souza Filho AG, Alves OL (2014) Anti-adhesion and antibacterial activity of silver nanoparticles supported on graphene oxide sheets. Colloid Surf B 113:115–124
4. El-Shanshoury A.E.-R.R., ElSilk S.E., Ebeid M.E. Extracellular biosynthesis of silver nanoparticles using escherichia coli ATCC 8739, bacillus subtilis atcc 6633, and streptococcus thermophilus esh1 and their antimicrobial activities. Int. Sch. Res. Not. 2011;2011:385480. doi: 10.5402/2011/385480.
5. Otari S.V., Patil R.M., Nadaf N.H., Ghosh S.J., Pawar S.H. Green synthesis of silver nanoparticles by microorganism using organic pollutant: Its antimicrobial and catalytic application. Environ. Sci. Pollut. Res. Int. 2014;21:1503–1513. doi: 10.1007/s11356-013-1764-0.
6. Banu A.N., Balasubramanian C., Moorthi P.V. Biosynthesis of silver nanoparticles using Bacillus thuringiensis against dengue vector, Aedes aegypti (Diptera: Culicidae) Parasitol. Res. 2014;113:311–316. doi: 10.1007/s00436-013-3656-0.
7. Thomas R., Janardhanan A., Varghese R.T., Soniya E.V., Mathew J., Radhakrishnan E.K. Antibacterial properties of silver nanoparticles synthesized by marine Ochrobactrum sp. Braz. J. Microbiol. 2015;45:1221–1227. doi: 10.1590/S1517-83822014000400012.
8. Monowar T., Rahman M.S., Bhore S.J., Raju G., Sathasivam K.V. Silver Nanoparticles Synthesized by Using the Endophytic Bacterium Pantoea ananatis are Promising Antimicrobial Agents against Multidrug Resistant Bacteria. Molecules. 2018;23:3220. doi: 10.3390/molecules23123220.
9. Saravanan M., Barik S.K., MubarakAli D., Prakash P., Pugazhendhi A. Synthesis of silver nanoparticles from Bacillus brevis (NCIM 2533) and their antibacterial activity against pathogenic bacteria. Microb. Pathog. 2018;116:221–226. doi: 10.1016/j.micpath.2018.01.038.
10. Iqtedar M., Aslam M., Akhyar M., Shehzaad A., Abdullah R., Kaleem A. Extracellular biosynthesis, characterization, optimization of silver nanoparticles (Ag NPs) using Bacillus mojavensis BTCB15 and its antimicrobial activity against multidrug resistant pathogens. Prep. Biochem. Biotechnol. 2019;49:136–142. doi: 10.1080/10826068.2018.1550654.
11. Li G., He D., Qian Y., Guan B., Gao S., Cui Y., Yokoyama K., Wang L. Fungus-mediated green synthesis of silver nanoparticles using Aspergillus terreus. Int. J. Mol. Sci. 2011;13:466–476. doi: 10.3390/ijms13010466.
12. Devika R., Elumalai S., Manikandan E., Eswaramoorthy D. Biosynthesis of silver nanoparticles using the fungus Pleurotus Ostreatus and their antibacterial activity. Open Access Sci. Rep. 2012;12:557. doi: 10.4172/scientificreports.557.
13. Raudabaugh D.B., Tzolov M.B., Calabrese J.P., Overton B.E. Synthesis of silver nanoparticles by a bryophilous rhizoctonia species. Nanomater. Nanotechnol. 2013;3:2. doi: 10.5772/56207.
14. Fahmy T.A., Hussein H.E.-S., Mostafa M.E.-H., Mahmoud M.E., Dalia M.E.-A. Silver Nanoparticlesynthesized by enicillium citreonigrum and usarium moniliforme Isolated from El-Sharkia, Egypt. Int. J. Sci. Eng. Res. 2014;5:181–192.
15. Bhangale H., Sarode K., Patil A., Patil D. Microbial Synthesis of Silver Nanoparticles Using Aspergillus Flavus and Their Characterization. >ICATSA 2016:Techno-Societal 2016. 2018:463–470.

16. Ammar H.A., El-Desouky T.A. Green synthesis of nanosilver particles by Aspergillus terreus HA1N and Penicillium expansum HA2N and its antifungal activity against mycotoxigenic fungi. J. Appl. Microbiol. 2016;121:89–100. doi: 10.1111/jam.13140.
17. Lallawmawma H., Sathishkumar G., Sarathbabu S., Ghatak S., Sivaramakrishnan S., Gurusubramanian G., Kumar N.S. Synthesis of silver and gold nanoparticles using Jasminum nervosum leaf extract and its larvicidal activity against filarial and arboviral vector Culex quinquefasciatus Say (Diptera: Culicidae) Environ. Sci. Pollut. Res. Int. 2015;22:17753–17768. doi: 10.1007/s11356-015-5001-x.
18. Gurunathan S., Jeong J.K., Han J.W., Zhang X.F., Park J.H., Kim J.H. Multidimensional effects of biologically synthesized silver nanoparticles in Helicobacter pylori, Helicobacter felis, and human lung (L132) and lung carcinoma A549 cells. Nanoscale Res. Lett. 2015;10:35. doi: 10.1186/s11671-015-0747-0.
19. Parveen A., Rao S. Cytotoxicity and genotoxicity of biosynthesized gold and silver nanoparticles on human cancer cell lines. J. Clust. Sci. 2015;26:775–788. doi: 10.1007/s10876-014-0744-y.
20. Peddi S.P., Sadeh B.A. Structural studies of silver nanoparticles obtained through single-step green synthesis. Mater. Sci. Eng. 2015;92:012004. doi: 10.1088/1757-899X/92/1/012004.
21. Dhand V., Soumya L., Bharadwaj S., Chakra S., Bhatt D., Sreedhar B. Green synthesis of silver nanoparticles using coffea arabica seed extract and its antibacterial activity. Mater. Sci. Eng. C. 2016;58:36–43. doi: 10.1016/j.msec.2015.08.018.
22. Ganaie S., Abbasi T., Abbasi S. Rapid and green synthesis of bimetallic Au–Ag nanoparticles using an otherwise worthless weed Antigonon leptopus. J. Exp. Nanosci. 2016;11:395–417. doi: 10.1080/17458080.2015.1070311.
23. Parveen M., Ahmad F., Malla A.M., Azaz S. Microwave-assisted green synthesis of silver nanoparticles from Fraxinus excelsior leaf extract and its antioxidant assay. Appl. Nanosci. 2016;6:267–276. doi: 10.1007/s13204-015-0433-7.
24. Singh J., Dutta T., Kim K.H., Rawat M., Samddar P., Kumar P. 'Green' synthesis of metals and their oxide nanoparticles: Applications for environmental remediation. J. Nanobiotechnol. 2018;16:84. doi: 10.1186/s12951-018-0408-4.
25. Zhang Q., Li N., Goebl J., Lu Z., Yin Y. A systematic study of the synthesis of silver nanoplates: Is citrate a "magic" reagent? J. Am. Chem. Soc. 2011;133:18931–18939. doi: 10.1021/ja2080345.
26. Shameli K., Ahmad M.B., Yunus W.Z., Ibrahim N.A., Darroudi M. Synthesis and characterization of silver/talc nanocomposites using the wet chemical reduction method. Int. J. Nanomed. 2010;5:743–751. doi: 10.2147/IJN.S13227.
27. Martinez-Castanon G., Nino-Martinez N., Martinez-Gutierrez F., Martinez-Mendoza J., Ruiz F. Synthesis and antibacterial activity of silver nanoparticles with different sizes. J. Nanopart. Res. 2008;10:1343–1348. doi: 10.1007/s11051-008-9428-6.
28. De Matteis V., Malvindi M.A., Galeone A., Brunetti V., De Luca E., Kote S., Kshirsagar P., Sabella S., Bardi G., Pompa P.P. Negligible particle-specific toxicity mechanism of silver nanoparticles: The role of Ag+ ion release in the cytosol. Nanomedicine. 2015;11:731–739. doi: 10.1016/j.nano.2014.11.002.
29. Agnihotri S., Mukherji S., Mukherji S. Size-controlled silver nanoparticles synthesized over the range 5–100 nm using the same protocol and their antibacterial efficacy. RSC Adv. 2014;4:3974–3983. doi: 10.1039/C3RA44507K.
30. Guzmán M.G., Dille J., Godet S. Synthesis of silver nanoparticles by chemical reduction method and their antibacterial activity. Int. J. Chem. Eng. 2009;2:104–111.
31. Pinto V.V., Ferreira M.J., Silva R., Santos H.A., Silva F., Pereira C.M. Long time effect on the stability of silver nanoparticles in aqueous medium: Effect of the synthesis and storage conditions. Colloids Surf. A Phys. Eng. Asp. 2010;364:19–25. doi: 10.1016/j.colsurfa.2010.04.015.
32. Reetz M.T., Helbig W. Size-selective synthesis of nanostructured transition metal clusters. J. Am. Chem. Soc. 1994;116:7401–7402. doi: 10.1021/ja00095a051.
33. Zhang Y., Chen F., Zhuang J., Tang Y., Wang D., Wang Y., Dong A., Ren N. Synthesis of silver nanoparticles via electrochemical reduction on compact zeolite film modified electrodes. Chem. Commun. 2002;23:2814–2815. doi: 10.1039/b208222e.
34. Roldán M., Pellegri N., de Sanctis O. Electrochemical method for Ag-PEG nanoparticles synthesis. J. Nanopart. Res. 2013;2013:524150. doi: 10.1155/2013/524150.
35. Jin R., Cao Y.C., Hao E., Métraux G.S., Schatz G.C., Mirkin C.A. Controlling anisotropic nanoparticle growth through plasmon excitation. Nature. 2003;425:487–490. doi: 10.1038/nature02020.
36. Huang L., Zhai M.L., Long D.W., Peng J., Xu L., Wu G.Z., Li J.Q., Wei G.S. UV-induced synthesis, characterization and formation mechanism of silver nanoparticles in alkalic carboxymethylated chitosan solution. J. Nanopart. Res. 2008;10:1193–1202. doi: 10.1007/s11051-007-9353-0.
37. Manikprabhu D., Lingappa K. Microwave assisted rapid and green synthesis of silver nanoparticles using a pigment produced by Streptomyces coelicolor klmp33. Bioinorg. Chem. Appl. 2013;2013:341798. doi: 10.1155/2013/341798.
38. Zhou Y., Zhao Y., Wang L., Xu L., Zhai M., Wei S. Radiation synthesis and characterization of nanosilver/gelatin/carboxymethyl chitosan hydrogel. Radiat. Phys. Chem. 2012;81:553–560. doi: 10.1016/j.radphyschem.2012.01.014.
39. Pingali K.C., Rockstraw D.A., Deng S. Silver nanoparticles from ultrasonic spray pyrolysis of aqueous silver nitrate. Aerosol Sci. Technol. 2005;39:1010–1014. doi: 10.1080/02786820500380255.
40. Sotiriou G.A., Teleki A., Camenzind A., Krumeich F., Meyer A., Panke S., Pratsinis S.E. Nanosilver on nanostructured silica: Antibacterial activity and Ag surface area. Chem. Eng. J. 2011;170:547–554. doi: 10.1016/j.cej.2011.01.099.
41. Ge L., Li Q., Wang M., Ouyang J., Li X., Xing M.M. Nanosilver particles in medical applications: Synthesis, performance, and toxicity. Int. J. Nanomed. 2014;9:2399–2407.
42. Iravani S., Korbekandi H., Mirmohammadi S.V., Zolfaghari B. Synthesis of silver nanoparticles: Chemical, physical and biological methods. Res. Pharm. Sci. 2014;9:385–406.
43. El-Nour K.M.A., Eftaiha A., Al-Warthan A., Ammar R.A. Synthesis and applications of silver nanoparticles. Arab. J. Chem. 2010;3:135–140. doi: 10.1016/j.arabjc.2010.04.008.

44. Nakamura M., Oyane A., Shimizu Y., Miyata S., Saeki A., Miyaji H. Physicochemical fabrication of antibacterial calcium phosphate submicrospheres with dispersed silver nanoparticles via coprecipitation and photoreduction under laser irradiation. Acta Biomater. 2016;46:299–307. doi: 10.1016/j.actbio.2016.09.015.

45. J. L. Elechiguerra, J. L. Burt, J. R. Morones et al., "Interaction of silver nanoparticles with HIV-1," *Journal of Nanobiotechnology*, vol. 3, article 6, 2005.

46. R. J. Coker, B. M. Hunter, J. W. Rudge, M. Liverani, and P. Hanvoravongchai, "Emerging infectious diseases in southeast Asia: regional challenges to control," *The Lancet*, vol. 377, no. 9765, pp. 599–609, 2011.