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GREEN SYNTHESIS AND APPLICATIONS OF SILVER NANO PARTICLES

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ABSTRACT

The topic focused on a review of the green synthesis and applications of silver nanoparticles (AgNPs), which can be utilized in biomedical research. An environment friendly extracellular biosynthetic technique for the production of the silver nanoparticle has been studied. The reducing agents used to produce the nanoparticles were from aqueous extracts made from the leaves of various plants. The nanoparticles were characterized by UV-visible Spectrophotometer. The nanoparticles were found have the size ranges from 160-180 nm. The most obvious merits of green synthesis are the increased biocompatibility of the resulting silver nanoparticles and the ease with which the reactions can be carried out.

KEYWORD: green synthesis and applications of silver nanoparticles (AgNPs).

INTRODUCTION

Due to swift industrialization, our environment undergo huge smash up and superfluous chemical gases or substances are released, and so now it is our need to learn about the secrets that are present in the nature and it's product which leads to the growth of advancements in the synthesis process of nanoparticles.[1]

Plants provide a better platform for nanoparticles synthesis as they are free from toxic chemicals as well as provide natural capping agent. Moreover, use of plant extract also reduces the cost of microorganism isolation and culture media enhancing the cost competitive feasibility over nanoparticles synthesis by microorganisms.[2]

Disease-causing microbes that have become resistant to drug therapy are an increasing public health problem. Many researchers are now engaged in developing new effective antimicrobial reagents with the emergence and increase of microbial organisms resistant to multiple antibiotics, which will increase the cost of health care. Therefore, there is an urgent need to develop new bactericides. Silver has been used for years in the medical field for antimicrobial applications such as burn treatment, elimination of microorganisms on textile fabrics, disinfection in water treatment, prevention of bacteria colonization on catheters etc. It has also been found to prevent HIV from binding to host cells, but the effects of silver nanoparticles (AgNPs) on microorganisms have not been developed fully. Nanosilver being less reactive than silver ions, is expected to be more suitable for medical applications.[3]

Reducing the particle size of metals is also an efficient and reliable tool for improving their biocompatibility, which facilitates their applications in different fields such as bioscience and medicine.[4]

There have also been several experiments performed on the synthesis of silver nanoparticles using medicinal plants such as Oryza sativa, Helianthus annus, Saccharumofficinarum, Sorghum bicolour, Zea mays, Basellaalba, Aloe vera, Capsicum annum, Cinnamomumcamphora and Geranium species in the field of pharmaceutical application and biological industries. In the recent days, silver nanoparticles have been synthesized from the naturally occurring sources and their products like green tea (Camellia sinensis), neem (Azadirachtaindica), various leaf broth, natural rubber, starch, aloe Vera plant extract etc.

Nanotechnology

It is an important field of modern research dealing with design, synthesis and manipulation of particle structure ranging from approximately 1-100nm in one dimension. Nanotechnology is rapidly gaining importance in number of areas such ashealth care, cosmetics, food, environmental health,biomedical drug gene delivery, energy science, optoelectronics, catalyst, light emitters, non-linear optical devices and photo electro chemical application.[5]

Nanoparticles

The term 'nano particles' is used to describe a particle with size in the range of 1-100nm, at least in one of the three dimensions. Nano particles can made using certain materials like metals, metal oxide, silicates, non-oxide

ceramics, polymers, organics, carbon, and bio molecule. Nano particles exist in several different morphologies such as spheres, cylinders, platelets, tubes etc.[5]

Types of nano particles

Nanoparticles can be broadly grouped into two, namely, organic nanoparticles which include carbon nanoparticles (fullerenes) while, some of the inorganic nanoparticles include magnetic nanoparticles, noble metal nanoparticles(like gold and silver) and semiconductors nanoparticles (like titanium oxide, zinc oxide).

There is growing interest in inorganic nano particles i.e.; of noble metal nanoparticles (gold &silver) have been widely used for cellular delivery due to their versatile features like wide availability, rich functionality, good compatibility capability of targeted drug delivery and controlled release of drug.[5]

SILVER NANO PARTICLES

Silver is colloidal state exhibits distinctive properties, such as good conductivity, chemical stability, catalytic and anti bacterial activity. The medical properties of silver have been known for over 2,000 years. Since the nineteenth century,silver-based compounds have been used in many antimicrobial applications. Nanoparticles have been known to be used for numerous physical,biological, and pharmaceutical applications. It is a well-known fact that silver ions and silver-based compounds are highlytoxic to microorganisms which include 16 major species of bacteria. Silver nanoparticles are non toxic, safe and anti bacterial agent that is capable of killing about 650 types of disease causing microorganisms. They have a specific surface area and a high fraction of surface atoms, because of the unique physicochemical characteristics of nanoparticles including catalytic activity, optical properties, electronic properties, anti bacterial activity magnetic properties.[6]

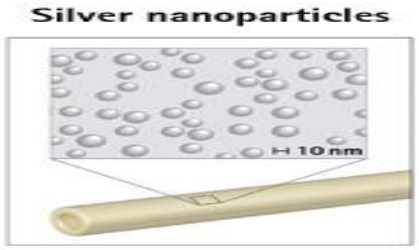

Fig4: silver nano particles

MECHANISM OF ACTION

The AgNPshave the ability to anchor to the bacterial cell wall and subsequently penetrate it, thereby causing structural change deals of cell membrane like the permeability of the cell membrane and death of thecell. There is formation of 'pits' on the cell surface and there is accumulation of the nanoparticles on the cell surface.[15-18]

Next is that the formation of free radicals by the silver nano particles when in contact with the bacteria, and free radicals have been ability to damage the cell membrane and it make it porous which can ultimately lead to cell death. It has also been proposed that there can be released of silver ions by the nano particles.And there ions can interact with the thiol group of many vital enzymes and inactivate them.[16]

The bacterial cell in contact with the silver cake in silver ions, which inhibit several functions in the cell and damages the cells. Then, there is the generation of reactive oxygen species, which are produced possibly through the inhibition of a respiratory enzyme by silver ions and attack the cell itself.

Silver is a soft acid, and there is natural tendency of an acid to react with a base in this case, a soft acid to react with a soft base. The action there nano particles on the cell can cause the reaction to take place and subsequently lead to cell death.[15-18]

Another fact is that the DNA has sulfur and phosphorus as its major components; the nanoparticles can act on the soft bases and destroy the DNA which would definitely lead to cell death. The interaction of the silver nanoparticles with sulfur and phosphorus of the DNA can lead to the problems in the DNA replication of the bacteria and thus terminate the microbes.

It is a well established fact that phosphorylation of protein substrate in bacteria influences bacterial signal transduction. Dephosphorylation is noted only in the tyrosine residue of gram negative bacteria. The phosphotyrosine profile of bacterial peptides is altered by the nano particles. It was found that the nanoparticles depth sporylate the peptide substrate on tyrosine residue, which leads to signal transduction inhibition and thus stoppage of growth.[15-18]

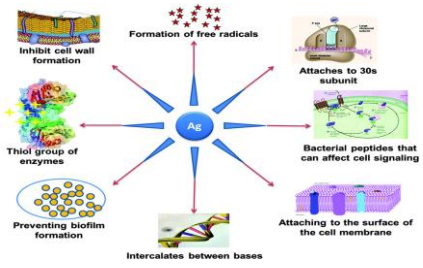

Fig5: Various modes of action of silver nano particles on bactria

USES OF SILVER NANOPARTICLES

a. Chemotherapy

The green synthesis is that the drug is transported without highly toxic compounds, the drug is released without harmful radiation or relying on the specific chemical reaction to occur and the drug can be selectively released at a targeted tissue.

For example; once the nanoparticle drug complex enters or is in the vicinity of the target tissues or cells, a glutathione monoester can be administered to the site. The nucleophilic ester oxygen will attach to the

functionalized surface of the nanoparticles through a new ester linkage while the drug is released to surroundings. The drug is now active and can exert its biological function on the cells immediate to its surroundings limiting non-desirable interactions with other tissues.[20]

b. Antimicrobial

It has been noted that the introduction of silver nanoparticles has shown to have synergistic activity with common antibiotics like penicillin G, ampicillin, erythromycin, clindamycin and vancomycin against E.coli and S.aureus.[20,21]

c. Catalysis

Silver nanoparticles have been demonstrated to show catalytic redox properties for dyes, benzene, carbon monoxide and likely other compounds.[20]

d. Silver nano wires biosensors

They are being developed for a wide range of disease diagnostics.[21]

e. Aid in drug delivery

Silver nanoparticles are known to increase the efficiency of drug delivery.[20]

NEED OF GREEN SYNTHESIS

Nanoparticles can be synthesized using various approaches including chemical, physical and biological. Biosynthesis of nano particles is a kind of bottom up approach where the main reaction occurring in reduction or oxidation. The need for biosynthesis of nano particles rose as the physical and chemical processes were costly; Although chemical methods of synthesis require short period of time for synthesis of large quantity of nanoparticles, chemical synthesis method leads to presence of some of the toxic chemical absorbed on the surface that may have adverse effect in the medical application. This method requires capping agent for size stabilization of nanoparticles. Chemicals used for nanoparticles synthesis and stabilization are toxic and lead to non eco-friendly byproducts. This is not an issue when it comes to biosynthesized nanoparticles via green synthesis route. So in the search of cheapest pathway for nanoparticles synthesis, scientist used microbial enzymes and plant extract (phytochemicals). With their antioxidant or reducing properties, they are usually responsible for the reduction of metal compounds in to their respective nanoparticles. Green synthesis provides advancement over chemical and physical method as it is cost effective, environment friendly, easily scaled up for large scale synthesis and in this method, there is no need to use high pressure, energy, temperature and toxic chemicals.[7,8]

MATERIALS USED FOR GREEN SYNTHESIS

Various biological entities, including plant extracts (Leonurus japonicus, Artemisia capillaris, Polygala tenuifolia, and Caesalpi niasappan), a pure compound from plants (chlorogenic acid), polysaccharides (chondroitin sulfate and acharan sulfate), an oligosaccharide (sialyl lactose) and invertebrate extracts(an African giant snail, Achatina fulica and an earthworm, Eisenia andrei),used as materials for the green synthesis of AgNPs.[9]

STEPS INVOLVED IN GREEN SYNTHESIS OF THE SILVER NANO PARTICLES

Step 1 - Preparation of the leaf extract

Fresh and healthy leaves of certain plants were collected locally and rinsed thoroughly first with tap water followed by distilled water to remove all the dust and unwanted visible particles, cut into small pieces and dried at room temperature. About 10 g of these finely incised leaves of each plant type were weighed separately and transferred into 250 ml beakers containing 100 ml distilled water and boiled for about 20 min. The extracts were then filtered thrice through Whatman No. 1 filter paper to remove particulate matter and to get clear solutions which were then refrigerated (4°C) in 250 ml Erlenmeyer flasks for further experiments. In each and every steps of the experiment, sterility conditions were maintained for the effectiveness and accuracy in results without contamination.[11,12]

Step 2 - Silver nano particle (Ag NP) synthesis

Aqueous solution (1 ml) of silver nitrate ($AgNO_3$) was prepared in 250 ml Erlenmeyer flasks and leaf extract was added for reduction into Ag^+ ions for each type of leaf extract. The composite mixture was then kept on turntable of the microwave oven for complete bio reduction at a power of 300 W for 4 min discontinuously to prevent an increase of pressure. In the mean time, the colour change of the mixture from faint light to yellowish brown to reddish brown to colloidal brown was monitored periodically. Complete reduction of $AgNO_3$ to Ag^+ ions was confirmed by the change in colour from colourless to colloidal brown.[11,12] After irradiation, the dilute colloidal solution was cooled to room temperature and kept aside for 24h for complete bio reduction and saturation denoted by UV-visible spectrophotometric scanning. The formation of Ag NPs was furthermore confirmed by spectrophotometric analysis.(13)

The factors like reaction time, temperature and concentration of silver nitrate that affected the synthesis of silver nanoparticles.

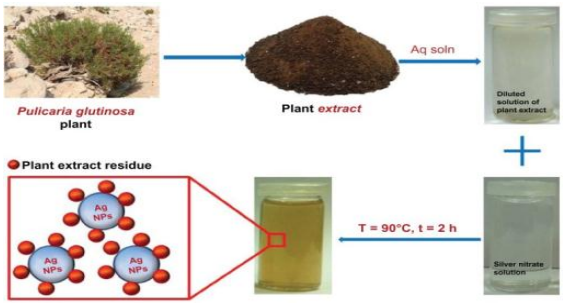

Fig7: synthesis of silver nano particles

Table 1: List of Plant extracts used for the green synthesis of antibacterial silver nano particles.[10]

SI:No	Scientific name	Intrinsic biological activities of plants	Plant part used
1	Acalyphaindica	1)Analgesic and Anti inflammatory activities. 2)Anti tuberculosis activity 3)Anti bacterial activity	Leaves
2	Allium cepa	1) antimicrobial activity	Bulbs
3	Argemonemaxicana	1)Healingof gastric ulceration.	Leaves
4	Artemisia capillaries	1)Antitumoractivity 2)Antiobesity activity 3)Antiinflammatory activity.	Aerial parts
5	Artocarpusheterophyllus	1)Antiproliferative activity 2)Antimicrobial activity 3) Antioxidant activity 4)Hypoglycemic and Hypolipidemic effects.	Leaves
6	Azadirachtaindica	1)Antiinflammatory activity 2)Antioxidantand Antiproliferative activities.	Leaves
7	Boswelliaovalifoliolata	1) Antioxidant activity	Stem barks
8	Caesalpiniasappan	1)Antiinflammatory activity 2)Vasorelaxant activity.	Heartwoods
9	Camellia sinensis	1) Antioxidant activity 2)Blood anticoagulation 3)Neuroprotective effect 4)Antimicrobial activity 5) Hypoglycaemic and Hypolipidemic activities 6)Wound healing activity.	Leaves
10	Carica papaya	1)Antiplasmodial activity 2) Antioxidant activity 3)Anxiolytic and Sedative effects.	Fruits
11	Catharanthusroseus	1) Antidiabetic activity 2)Hypolipidemic activity 3)AchEinhibitory activity.	Leaves
12	Chrysanthemum morifolium	1)Antiinflammatory activity 2) Anti HIV activity 3) Antitumor activity.	Flower
13	Cinnamon zeylanicum	1)Improves insulin sensitivity in the brain 2)Antihypertension effect 3)Effects neurodegenerative diseases and its potent.	Bark
14	Citrulluscolocynthis	1)Antimicrobial potentials 2)Analgesic and Antiinflammatory activities 3) Antibacterial activity 4) Antioxidant activity 5) Antitumor activity.	Leaves
15	Citrus sinensis	1)Antioxidant and Antifungal activities	Peel
16	Coleus aromaticus	1)Wound healing activity 2) Diuretic activity.	Leaves
17	Coleus forskohlii	1)Wound healing activity 2) Anti HIV activity 3) Diuretic activity 4) Antifungal activity.	Root
18	Curcuma longa	1)Antioxidant, Antiinflammatory 2)Hepatoprotective effect.	Tuber
19	Desmodiumtriflorum	1) Antibacterial activity 2) Antitumor activity 3) Antidiabetic activity 4)Analgesic and Antiinflammatory activities.	whole plant
20	Dioscoreabatatas	1)Antiinflammatory activity 2) Antioxidant activity	Rhizome
21	Dioscoreabulbifera	1) Antibacterial activity	Tuber

		2) Antitumor activity 3) Antidiabetic activity	
22	Eucalyptus citriodora	1)Antiinflammatory activity 2) Analgesic activity 3)Antiproliferative effect 4) Antituberculosis 5) Antibacterial activity	Leaves
23	Euphorbia hirta	1)Antimicrobial activity 2)Antidiabetic and Antioxidant potentials 3)Immunomodulatory activity 4)Antianaphylactic effect 5) Burn-wound healing activity 6)Antidiarrhoeic activity 8)Analgesic, Antipyretic and Antiinflammatory properties.	Leaves
24	Euphorbia nivulia	1)Wound healing activity 2) Haemostatic activity 3) Antibacterial activity	Latex
25	Garciniamangostana	1)Neuroprotective effect 2)Antiinflammatory efffect 3)Antioxidant and Anttumor activity 4)Antimicrobial and Antiprotozoal activities 5)Antiangiogenic effect 6)Analgesic activity	Leaves
26	Hibiscus sabdariffa	1)Nephroprotective effect 2) Antimicrobial effect 3)Hypolipidemic activity 4)Wound healing activity 5) Antidiabetic activity 6) Diuretic effect 7) Antioxidant activity.	Leaves, stem
27	Leonurus japonicas	1) Antioxidant activity 2) Anticancer activity 3)Cardioprotective effect 4) Antibacterial activity 5)Antiinflammatory activity	Aerial parts
28	Menthapiperita	1)Prevents chemotherapy-induced nausea and vomiting 2) Antifungal activity 3) Antioxidant activity 4) Analgesic effect 5)Antispasmodic activity on rat trachea	Leaves
29	Mimusopselengi	1) Antioxidant activity	Fruits
30	Moringaoleifera	1)Antimicrobial, Anticancer, Antiinflammatory, Antidiabetic, and Antioxidant effects 2)Antidiabetic and Antioxidant activities 3)Antiinflammatory activity 4) Hypoglycemia and Hypolipidemia activities 5) Antioxidant capacity and Antimicrobial activities 6) Antifungal activity 7)Recovery from hepatic damage 8)Antispasmodic, Antiinflammatory and Diuretic activities.	Leaves
31	Musa paradisiacal	1)Antioxidant, Antimutagenic, Anticarcinogenic, and Cytoprotective activities.	Peel
32	Neriumindicum	1) Antifungal activity	Leaves

		2) Antioxidant activity 3) Anticancer effects 4) Antidiabetic activity.	
33	Ocimumtenuiflorum	1)Antihyperglycemic activity	Leaves
34	Opuntiaficusindica	1)Activity of the coagulants 2) Antibacterial activity 3)Inhibits the ulcerogenic activity 4)Wound healing activity 5)Reduces hangover symptoms and inhibites the production of inflammatory mediators 6)Hepatoprotective effect.	
35	Polygala tenuifolia	1)Antiinflammatory activity 2) Antitumor activity 3) Anxiolytic activity.	Roots
36	Sesuviumportulacastrum	1)Potential antimicrobial agent 2)Cholinesterase inhibitory activity	Leaves, callus
37	Shoreatumbuggaia	1) Decreases cholesterol andtriglycerides	stem barks
38	Tribulusterrestris	1) Antitumor activity 2)Conventional analgesic drugs 3)Antihypertensive effect both systolic and diastolic 4)Antidepressive effect.	Fruits
39	Vitexnegundo	1)Treats various inflammatory disorders 2)Analgesic and Antiinflammatory activities	Leaves

ADVANTAGES OF GREEN SYNTESIS OF SILVER NANO PARTICLES[19]

- Green synthesis is simple and cost-effective.
- Green biological entities can be used as reducing agents and capping agents. Colloidal stability is an important factor when making claims regarding the biological activity of AgNPs.
- They are easily available, Safe and nontoxic in most cases and
- They have a broad variety of metabolites that can aid in the reduction of silver ions, and are quicker than microbes in the synthesis**.**

DISADVANTAGES OF GREEN SYNTHESIS OF SILVER NANO PARTICLES[19]

- The adverse effects of these free silver ions on humans and all living beings include permanent bluish-gray discoloration of the skin (argyria) or the eyes (argyrosis).
- exposure to soluble silver compounds may produce toxic effects like liver and kidney damage; eye, skin, respiratory, and intestinal tract irritations; and untoward changes in blood cells.
- silver can also cause some environmental problems due to its antimicrobial properties (antibacterial).

PHARMACEUTICAL AND MEDICINAL APPLICATIONS OF SILVER NANO PARTICLES[23]

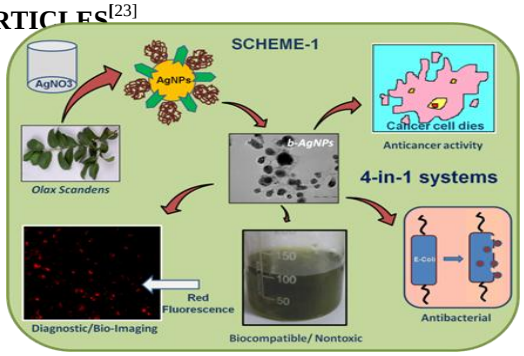

Fig 5: schematic representation of application of AgNPs

- Treatment of dermatitis; inhibition of HIV-1 replication.
- Treatment of ulcerative colitis & acne.
- Remote laser light-induced opening of microcapsules.
- Molecular imaging of cancer cells.
- Detection of viral structures (SERS & Silver nanorods).
- Coating of hospital textile (surgical gowns, face mask).
- Hydrogel for wound dressing Dentistry.
- Polyethylene tubes filled with fibrin sponge embedded with AgNPs dispersion.
- Biomedical applications such as antimicrobial applications, drug delivery vehicles, medical imaging and diagnostics.
- It have extensively reviewed AgNPs in a variety of applications, including anticancer, catalysis,

biosensor, drug delivery, textiles and cosmetics, antituberculosis, antiviral, insect management and water purification.

CONCLUSION

Silver nanoparticles (AgNPs) were successfully obtained from bioreduction of silver nitrate solutions using certain plant extracts.The green synthesis of nanoparticles has received an increasing attention because of its maximize efficiency and minimize health and environmental hazards as compared to the other conventional chemical synthesis. It is confirmed that silver nanoparticles are capable of rendering high antimicrobial efficacy and hence has a great potential in the field of medicine. Silver nanoparticles have been used extensively as antimicrobial agents in health industry, food storage, textile coatings and a number of environmental applications.

REFERENCE

1. Harekrishna Bar, D.K.B.,Gobinda sahoo P, priyanka Sarkar, Sankar PD.,"Green synthesis of silvernanoparticles using latex of Jatropha curcas.". Colliod surface A, 2009; 39(3): 134-139.
2. Cassandra D, N.N.,Jodi H, Linfeng G, Tan, Li, et al. ,"Green synthesis of gold and silver nanoparticles from plant extracts.".
3. Kaviya S, S.J.,Viswanathan B., "Green Synthesis of silver nanoparticles using Polyalthia longifolia Leaf extract along with D-Sorbitol.". Journal of nanotechnology, 2011; 1-5.
4. Catauro M, R.M., De Gaaetano FD, Marotta A, "Sol–gel processing of drug delivery materials and release kinetics.". J Mater Sci Mater Med, 2005; 16(3): 261-265.
5. Crabtree JH, B.R.,Siddiqi Ra, Huen IT, Handott LL, Fishman A, "The efficacy of silver-ion implanted catheters in reducing peritoneal dialysis-related infections.".Perit Dial Int, 2003; 23(4): 368-374.
6. Krolikowska A,K.A., Michota A,Bukowska J, "SERS studies on the structure of thioglycolic acid monolayers on silver and gold.".Surf Sci., 2003; 532: 227-232.
7. Zhao G, S.J., "Multiple parameters for the comprehensiveevaluation of the susceptibility of Escherichia coli to the silver ion.". Biometals, 1998; 11: 27.
8. Jiang H, M.S., Wong ACL, Denes FS, "Plasma enhanced deposition of silver nanoparticles onto polymer and metal surfaces for the generation of antimicrobial characteristics.". J Appl Polym Sci., 2004; 93: 1411-1422.
9. Duran N, M.P.,Alves OL, De Souza GIH, Esposito E,"Mechanistic aspects of biosynthesis of silver nanoparticles by several Fusarium oxysporum strains.". JNanobiotechnol, 2005; 3: 8-14.
10. RO, B., "Silver ions in the treatment of local infections.". Met Based Drugs, 1999; 6: 297-300.
11. Klaus T, J.R.,Olsson E, Granqvist C-G, "Silverbased crystalline nanoparticles, microbially fabricated.".Proc Natl Acad Sci USA,1999; 96: 13611-13614.
12. Garima Singhal, R.B.,Kunal Kasariya, Ashish Ranjan Sharma, Rajendra Pal Singh,"Biosynthesis of silver nanoparticles using Ocimum sanctum (Tulsi) leaf Page | 57extract and screening its antimicrobial activity.".J Nanopart Res., 2011; 13: 2981-2988.
13. Mukherjee P,A.A.,Mandal DS,Senapati S,Sainkar R,Khan MI, Parishcha R, Ajaykumar PV, Alam M, Kumar R,Sastry M,"Fungus-mediated synthesis ofsilver nanoparticles and their immobilization in the mycelial matrix: a novel biological approach to nanoparticle synthesis.". Nano Lett, 2001;.1: 515-519.
14. H.J.Lee, S. G.Lee, E. J.Oh, H. Y.Chung, S. I.Han, and E. J. Kim. Antimicrobial polyethyleneimine-silver nanoparticles in a stable colloidal dispersion. Colloid Surf. B: Biointerfaces, 2011; 88: 505-511.
15. M.H.El-Rafie, Th.I.Shaheen, A.A. Mohamed, and A. Hebeish. Bio-synthesis and applications of silver nanoparticles onto cotton fabrics. Carbohyd. Polym, 2012; 90: 915-920.
16. van den Wildenberg W. Roadmap report on nanoparticles. W&W Espana sl, Barcelona, Spain Gratzel M (2001) Photoelectrochemical cells. Nature, 2005; 414: 338–344.
17. Okuda M, Kobayashi Y, Suzuki K, Sonoda K, Kondoh T, Wagawa A, Kondo A,Yoshimura H. Self-organized inorganic nanoparticle arrays on protein lattices. Nano Lett, 2005; 5: 991–993.
18. Dai J, Bruening ML. Catalytic nanoparticles formed by reduction of metal ions in multilayered polyelectrolyte films. Nano Lett, 2002; 2: 497–501.
19. Murray CB, Sun S, Doyle H, Betley T. Monodisperse 3d transitionmetal (Co, Ni, Fe) nanoparticles. MRS Bull, 2001; 26: 985–9911.
20. Thorley, A.J. and Tetley, T.D. New perspectives innanomedicine. Pharmacol. Ther., 2013; 140: 176-185.
21. Aruguete, D.M., Kim, B., Hochella, M.F. Jr., Ma, Y.,Cheng,Y., Hoegh, A., Liu, J. and Pruden, A. Antimicrobialnanotechnology: its potential for the effective management ofmicrobial drug resistance and implications for research needsin microbial nanotoxicology. Environ. Sci. Processes Impacts, 2013; 15: 93-102.
22. Pelgrift, R.Y. and Friedman, A.J. Nanotechnology as atherapeutic tool to combat microbial resistance. Adv. DrugDelivery Rev., 2013; 65: 1803-1815.
23. Seil, J.T. and Webster, T.J. Antimicrobial applicationsof nanotechnology: methods and literature. Int. J. Nanomed., 2012; 7: 2767-2781.
24. Loomba, L. and Scarabelli, T. Metallic nanoparticlesand their medicinal potential. Part I:gold and silver colloids.Ther. Delivery, 2013; 4: 859-873.

25. A Nanda and M. Saravanan, Biosynthesis of silver nanoparticles from Staphylococcus aureus and its antimicrobial activity against MRSA and MRSE. Nanomedicine: Nanotechnol., Biol. and Medicine, 2009; 5: 452-456.