Biosynthesis of silver nanoparticle by eco-friendly method

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Abstract

In the recent time, synthesis of nanoparticles has been the subject of a lot of studies due to its commercial demands and wide applicability in various areas. Nanotechnology is an emerging field, nanoparticles is helpful in investigation and regulation at cell level interaction between synthetic and biological materials. In many areas of human science these materials are superior and indispensable due to its unique size dependent. Generally, physical, mechanical and chemical methods involved for the synthesis of nanoparticles. But these methods are very expensive and some methods involve harmful chemicals. With the aim of developing clean, nontoxic and eco-friendly technologies, a wide range of biological sources has been used for the formation of particle. Green chemistry processes led to eco-friendly method of synthesis and safe process as compared to other methods. In this review, we describe a cheap and environment friendly technique for synthesis of silver nanoparticles by green chemistry approached from different biological sources. The importance of this study includes the precise and specific analysis of silver nanoparticles, biological systems that may support and revolutionize the art of synthesis of nanoparticles.

Keywords: *Silver Nanoparticles, Green chemistry*

1. Introduction

Nanoparticles (nano-scale particles = NSPs) are atomic or molecular aggregates with at least one dimension between 1 and 100nm [1,2], that can drastically modify their physico-chemical properties compared to the bulk material [3]. Nanoparticles can be made from a fully variety of bulk materials and that they can explicate their actions depending on both the chemical composition and on the size and/or shape of the particles [4]. Because of its smaller structure, they trigger the chemical activity due to their distinctive crystallographic nature that increases surface area, hence the scope of reactivity [5]. The advance technology accepts that the concept of interdisciplinary research in the areas of engineering and sciences leads to creation of environmentally acceptable "green process", with special concern to nanoscience and nanotechnology. The formation of nanoparticles mediated by biological route is considered as better method than any other method because catalytic and functional information obtained under close to optimal conditions through action of enzymatic properties can help to understand the biochemical and molecular mechanisms of nanoparticles formation.

In nanotechnology, silver nanoparticles are the most promising one. Silver nanoparticles are nanoparticles of silver, i.e. silver particles size in range of between 1 nm and 100 and because of its nano size it have attracted intensive research interest. It is observed that silver nanoparticles do not affect living cells, so not able to provoke microbial resistance. It is believed that Silver nanoparticles can attach to the cell wall and disturb cell-wall permeability and cellular respiration[6]. Silver containing particles also used in textile fabrics, as food additives, and in package and plastics to eliminate microorganisms. Because of such a wide range of applications, various methods concerning the fabrication of silver nanoparticles, as well as various silver-based compounds containing metallic silver (Ag0) have been developed [7]. The special attention towards the silver nanoparticles because of their strong antimicrobial activity either in metallic nature and nanoparticles form also, so it is found that silver nanoparticles has different applications to the environment and human. It has been well studied that a variety of biological sources are able to produce silver nanoparticles of different shapes and nature. Nanoparticle production and applications have been extensively studied; studies related to drug delivery, tissue engineering and bioMEMS have been undertaken for a great number of scientific publications and patents. Some uses of Silver Nanoparticles are mentioned below-

- Minute amount of silver are particularly used as decontaminating agent in water and prevent biofilm formation in food contact surfaces [8].
- The antimicrobial nature of silver ions plays a prominent role in food packaging systems [9].
- Silver nanoparticles have antibacterial properties mediated by silver ions [10].
- It used as preservative in food and various food related products [11].
- The silver nanoparticles are reported to show better wound healing capacity, better cosmetic appearance and scar less healing

when tested using an animal model [12].

- The Fe3O4 attached silver nanoparticles can be used for the treatment of water and easily removed using magnetic field to avoid contamination of the environment [13].
- Environmental-friendly antimicrobial nanopaint can be developed [14].

The present review article draws attention to the current knowledge regarding the potential organisms for biosynthesis of silver nanoparticles and presents a database that future researchers can be based on.

2. Biosynthesis of Silver Nanoparticles

Living cell ranges from prokaryotic to eukaryotic are typically 10 mm across. Many varieties of biological sources available in nature including bacteria, algae ,yeast ,fungi, lower plants and higher angiosperm plant products can all be involved for the synthesis of nanoparticles. These ambient biological systems provide excellent examples of nanophasic materials with highly optimized characteristics resulting from evolution over a long scale of time [15] and the synthesis of inorganic materials may occur either extracellularly or intracellularly [16].

In current research areas of nanotechnology, with the help of biological source it is a big challenge to develop reliable experimental protocols for the synthesis of nanoparticles over a range of chemical composition, size and synchronized monodispersity that should be non-toxic, clean and eco-friendly. Although many paper have been reported in the last few years [17,18,19], it is need to elaborate this technology in a consolidated manner with an approach that gives an overview of the current trend of research on the biosynthesis of different metal nanoparticles and their applications. The use of environmentally benign materials like plant extract [20], bacteria [21], fungi [22] and enzymes [23] for the synthesis of silver nanoparticles offer many benefits of ecofriendliness and suitability for pharmaceutical and other biomedical applications as they do not use toxic chemicals for the synthesis protocol. A chemical synthesis method involves presence of some toxic chemical absorbed on the surface that may have adverse effect in the medical applications. Green synthesis provides advancement over chemical and physical method as it is cheap, ecofriendly, can be scaled up for large scale synthesis very easily and in this method there is no need to use high pressure, energy, temperature and toxic chemicals [24]. Herein, we provide an overview of various reports of biological means of nanoparticle synthesis of desired characteristics.

2.1 Biosynthesis of Silver Nanoparticle by Using Plant

Biosynthesis of nanoparticles by using plant materials includes very rapidly to reduction of metallic materials. This document provides detailed knowledge about the reduction of silver ions reaction much faster than the other any biological sources such as bacteria and fungi takes 1 to 5 days in contrast to plant the time required for complete reduction of the metal ions within hours. Now a days, use of plants for the formation of silver nanoparticles has drawn attention of researches because of its rapid, economical, eco-friendly protocol and it provides a single step technique for the biosynthesis process [25]. Silver nanoparticles have also gained significance due to their broad-spectrum activity against bacterial infections Flavonone and terpenoid components of leaf broth are being predicted to stabilize the formation of Nanoparticles in comparison to high molecular weight proteins of fungal biomass [26]. The polyol components and the water soluble heterocyclic components are mainly responsible for reduction of silver ions(Ag+)as well as stabilization of Nanoparticles. Information regarding the activity of reductases in nanoparticles fabrication are well illustrated [27]. No correlation is observed between the color development and increase in abundance exhibited by the synthesized nanoparticles. Differences in morphology of nanoparticles synthesized, is one possible reason for variation in optical properties [28].. It is well known that silver nanoparticles exhibit yellowish brown color in aqueous solution due to excitation of surface plasmon vibrations in silver nanoparticles [29]. Synthesized nano particles were characterized by using UV-visible spectrophotometer, Scanning Electron Microscope (SEM), X-ray diffractometer (XRD) and evaluated its antimicorbial property. Further studies reflect that several parameters together determine the Nanoparticle synthesis including plant source, the organic compounds in the crude leaf extract, the concentration of Silver Nitrate(AgNO3), the temperature and the pigments of the corresponding leaf extract [30].

Table 1. *Herbal Plant extract for synthesis of Silver Nanoparticles*

Herbal Plant Extract	References
Callus extract of Carica papaya	[31]
Latex of Jatropha curcas	[32]
Pelargonium graveolens (Geranium) leaf Extract	[34]
Argemone Mexicana Leaf Extract	[24]

Alfalfa Sprouts Extract	[33]
Carica papaya(Papaya) Fruit Extract	[29]
Cinnamomum camphora	[35]
Trianthema decandra	[36]
Euphorbia hirta.L	[37]
Parthenium leaf extract	[38]
Aloe vera plant Extract	[39]
Fruit extract of Emblica officinalis	[40]
Roots of Medicago sativa	[33]
Helianthus annus Extract	[30]

Table 2. *Medicinal Plants used for Synthesize of Silver Nano particles*

S.No	Latin name	Common name	Family name	Part used	Reference(s)
1	Plumbago rosea	Koduveli	Plumbaginaceae	Root	[41]
2	Hemidesmus indicus	Mahali	Asclepiadaceae	Root	[41]
3	Smilax china	Pavu	Smilacaceae	Root	[41]
4	Melia azadirachta	Vepampattai	Meliaceae	Bark	[41]
5	Acorus calamus	Vasambu	Araceae	Rhizome	[41]
6	Andropogon muricatus	Vetiver	Poaceae	Root	[41]
7	Berberis aristata	Maramanjal	Berberidaceae	Wood	[41]
8	Cedrus deodara	Devadaru	Pinaceae	Wood	[41]
9	Celastrus paniculatus	Cherupunnari	Celastraceae	Seed	[41]
10	Coriandrum sativum	Dhaniya	Apiaceae	Fruit	[41]
11	Cuminum cyminum	Jeeraga	Apiaceae	Fruit	[41]
12	Embelia ribes	Vilangam	Myrsinaceae	Fruit	[41]
13	Glycyrrhiza glabra	Athi madhuram	Fabaceae	Root / rhizome	[41]
14	Holarrhena antidysenterica	Kodagapalari	Apocynaceae	Seed	[41]
15	Negella sativa	Karunjeeragam	Apiaceae	Seed	[41]
16	Psoralea corylifolia	Karpokarasi	Fabaceae	Seed	[41]
17	Balsamodendron mukul	Gugulu	Burseraceae	Resin	[41]
18	Azadirachta indica	Neem	Meliaceae	Leaf	[42]

2.2 Biosynthesis of Silver Nanoparticle by using Bacteria

The use of bacterial strain for bio manufacturing of silver nanoparticles have advantages over the other biological sources because it is easy to handle and short period of cultivation. Bacterial strain generates well defined shapes such as pyramidal and hexagonal silver nanoparticles of up to 200 nm sizes. The produced nanoparticles were quantified by TEM, XRD to identify their different shaped crystals [43]. It have been reported that the magnetotactic bacterial strains were good candidate for nanoparticles synthesis [44]. Microbial synthesis of nanoparticles in both intracellular and extracellular form are observed efficiently from variety of bacterial strains. For the complete list of Bacterial Source please refer Table-3

Table 3. *Bacterial Strain used in the Formation of Silver Nanoparticles*

Bacterial Strain	Nature of Product/Localization	Refrences
Pseudomonas stutzeri AG259	Intracellular	[43]
Lactobacillus strains	Intracellular	[45]
Plectonema boryanum	Intracellular	[46]
Aeromonas sp. SH10	Intracellular	[47]
Bacillus megaterium D01	Intracellular	[47]
Lactobacillus sp. A09	Intracellular	[47]
Klebsiella pneumonia	Extracellular	[48]
Shewanella oneidensis	Extracellular	[49]
Morganella sp.	Extracellular	[50]
Bacillus licheniformis	Extracellular	[51][52][53]
Bacillus cereus	Extracellular	[54]
E. coli	Extracellular	[55]

2.3 Biosynthesis of Silver Nanoparticles by Using Fungi and Yeast

Fungus are easy to culture on large scale by solid substrate fermentation and thus can be large biomass is formed for processing or formation of silver nanoparticles. Fungi have tendency to form product intracellular as well as extracellular though it has high wall binding capacity and metal intake capacity. Extracellular production of silver nanoparticles was reported using silver tolerant yeast strain MKY3, which synthesized hexagonal silver nanoparticles (2-5nm) in log phase of growth. The proper condition for the synthesis of large scale quantities of silver nanoparticles also standardized and documented that was based on differential thawing of the samples[56].

Table 4. *Fungus and Yeast used in the Formation of Silver Nanoparticles*

Fungi/Yeast	Nature of Product	References
Verticillium	Intracellular	[57]
Phoma sp. 3.2883	Extracellular	[58]
Aspergillus fumigates	Extracellular	[59]
Trichoderma asperellum	Extracellular	[60]
Phaenerochaete chrysosporium	Extracellular	[61]
Cladosporium cladosporioides	Extracellular	[62]
Penicillium sp.	Extracellular	[63]
P. brevicompactum	Extracellular	[64]
Phytophthora infestans	-	[65]
Fusarium oxysporumPTCC 5115	-	[66]

2.4 Biosynthesis of Silver Nanoparticles by using Algae

Review of literature revealed that the synthesis of nanoparticles using algae as source has been unexplored and underexploited. More recently, there are few, reported that algae being used as a biofactory for synthesis of metallic nanoparticles. Mushroom extract responsible for formation of silver, gold and silver-gold nanoparticles [67]. Marine alga is also used as a source for synthesis in Silver nanoparticle formation [68].

2.5 Biosynthesis of Nanoparticles by using Virus

Review of literature revealed that the synthesis of silver particle by using viral agent is still unexplored.

3. Future Perspective

Nanoscale technologies can be improved and brought about new area towards revolutionizing the fundamentals of disease diagnosis, treatment, therapy and prevention by innovating nanomedicines. Because of its small size, have the potential to alter molecular discoveries arising from genomics and proteomics which can be benefit for patients. The advantage of biological production systems is in the controlled production at a molecular level. Nanoparticles are formed in highly defined structures, complex morphologies and narrow particle size distribution [69]. As nanotechnology has gained interest in the last few years, and is expected to develop more in the future, the foremost challenge is to expand experimental protocols for the synthesis of silver nanoparticle by microbial sources, Fungal Sources and Plant sources. In addition, an enhanced understanding of the mechanism of the formation of nanoparticles and the bioreduction phenomenon of metal ions is needed. Today, with the help of modern technologies of impregnation of silver nanoparticles can solve the burning problem of resistance against antibiotics. Microbes are not able to develop resistance against silver, because they can develop against conventional and narrow target antibiotics. Metallic silver in the form of silver nanoparticles has made a beneficial comeback as a potential antimicrobial agent and has developed into diverse medical applications ranging from silver based dressings, silver coated medicinal devices, e.g. nanogels and nanolotions among others [70].

4. Conclusion

This paper has reviewed recent knowledge and built a data base of bioreductive approaches to formation of silver nanoparticles using different biological systems. The exact mechanism for the formation of nanoparticle by using biological resources is still being investigated and several possible ways have been proposed [71]. Current aspects of process which includes biological sources should focus towards the use of highly structured physical and biosynthetic activities of microbial cells to achieve better controlled manipulation of the size and shape of the particles. Furthermore effect is needed in order to develop more productive process for metallic nanoparticle production. In addition, improvements on biogenesis process are needed for the development of cheaper processes. It can be concluded that in microorganisms where proteins [72, 73] and angiosperms where carboxylic groups, amino groups, proteins and carbohydrates are present in the source extract, believed that play a key role in the biosorption and bioreduction process for the formation of nanoparticles. Lots of research work still need to be executed to understand the effect of time, temperature, light and other parameters regarding the phytoformation of Nanoparticles.

5. References

1. Ball P (2002) Natural strategies for the molecular engineer. Nanotechnol. 13, 15-28.
2. Roco MC (2003a) Broader societal issue of nanotechnology. J. Nanoparticle Res. 5,181-189
3. Nel A, Xia T, MadlerL and Li N (2006) Toxic potential of materials at the nanolevel. Sci. 311, 622-627
4. Brunner TI, Wick P, Manser P, Spohn P, Grass RN, Limbach LK, Bruinink A, and Stark WJ (2006) In vitro cytotoxicity of oxide nanoparticles: comparison to asbestos, silica, and effect of particle solubility. Environ. Sci. Technol. 40, 4374-4381.
5. Osaka T, Matsunaga T, Nakanishi T, Arakaki A, Niwa D and Iida H (2006) Synthesis of magnetic nanoparticles and their application to bioassays. Anal. Bioanal. Chem. 384, 593-600.
6. Singh M, Singh S, Prasad S, Gambhir IS (2008) Nanotechnology in medicine and antibacterial effect of silver nanoparticles. Digest J. Nanomaterials & Biostructures 3, 115-122.
7. David E, Elumalai EK, Prasad TNVKV, Venkata Kambala and Nagajyothi P.C. (2010) Green synthesis of silver nanoparticle using Euphorbia hirta L and their antifungal activities. Archives of Applied Science Research, 2(6), 76-81.
8. K.R. Sreekumari, Y. Sato and Y. Kikuchi // Mater. Trans. 46 2005 1636.
9. R.Kumar, S.Howdle and H.Munsted // Biomed. Mater. Res. B 75 (2005) 311.
10. C.N. Lok, C.M. Ho, R. Chen, Q.Y. He, W.Y.Yu and H. Sun // J. Proteome. Res. 5 (2006) 916.
11. A. Gupta and S. Silver // Nat. Biotechnol. 16 (1998) 888.
12. J. Tian, K.K.Y. Wong, C.M. Ho, C.N. Lok, W.Y. Yu and C.M. Che // Chem. Med. Chem. 00 (2006) 171.
13. P. Gong, H. Li, X. He, K. Wang, J. Hu and W. Tan // Nanotechnology 18 (2007) 604.
14. A.Kumar,P.K. Vemula, P.M. Ajayan and G. John // Nat. Mater. 7 (2008) 236.
15. Dickson DPE, 1999. Nanostructured magnetism in living systems. Journal of Magnetism and Magnetic Materials 203: 46-49.
16. Senapati S, Mandal D, Ahmad A, Khan MI, Sastry M, Kumar R, 2004. Fungus mediated synthesis of silver nanoparticles: a novel biological approach. Indian Journal of Physics A 78: 101-105.
17. Bhattacharya D, Rajinder G, 2005. Nanotechnology and potential of microorganisms. Critical Reviews in Biotechnology 25:199-204.
18. Mandal D, Bolander ME, Mukhopadhyay D, Sarkar G, Mukherjee P, 2006. The use of microorganisms for the formation of metal nanoparticles and their application. Applied Microbiology and Biotechnology 69: 485-492.
19. Mohanpuria P, Nisha K, Rana NK, Yadav SK, 2008. Biosynthesis of nanoparticles: technological concepts and future applications. Journal of Nanoparticle Research 10: 507–517.
20. Jain, D., Kumar Daima, S., Kachhwaha, S and Kothari, S.L. (2009) Synthesis of plant mediated silver nanoparticles using Papaya Fruit Extract And Evaluation of their Antimicrobial Activities. Digest Journal of Nanomaterials and Biostructures, 4(3), 557-56.
21. Saifuddin, N., Wong, C.W and Yasumira, A.A.N. (2009) Rapid Biosynthesis of silver nanoparticles using culture supernatant of bacteria with microwave irradiation. The Electronic Journal of Chemistry, 6(1), 61-70.
22. Verma, V.C., Kharwa, R.N and Gange, A.C. (2010) Biosynthesis of antimicrobial silver nanoparticles by the endophytic fungus Aspergillus clavatus. Journal of nanomedicine, 5(1), 33-40.
23. Willner, B., Basnar B and Willner B. (2007) Nanoparticle–enzyme hybrid systems for nanobiotechnology. FEBS Journal, 274,302–309 .
24. Singh, A., Jain, D., Upadhyay, M.K., Khandelwal and Verma, H.N. (2010) Green synthesis of silver nanoparticles using Argemone mexicana leaf extracts and evaluation of their antimicrobial activities. Digest Journal of Nanomaterials and Biostructures, 5,483-489.
25. Huang J, Li Q, Sun D, Lu Y, Su Y, Yang X, Wang H, Wang Y, Shao W, He N, Hong J, Chen C, 2007. Biosynthesis of silver and gold nanoparticles by novel sundried Cinnamomum camphora leaf. Nanotechnology 18: 105104-105115.

26. Shankar SS, Rai A, Ahmad A, Sastry MJ, 2004. Rapid synthesis of Au, Ag, and bimetallic Au core–Ag shell nanoparticles using Neem (Azadirachta indica) leaf broth. Journal of Colloid and Interface Science275: 496-502.

27. Kumar SA, Abyaneh MK, Gosavi SW, Kulkarni SK, Pasricha R, Ahmad A, Khan MI, 2007. Nitrate reductase-mediated synthesis of silver nanoparticles from AgNO3. Biotechnology Letters 29: 439-445.

28. Xu H. and Käll M, 2002. Morphology effects on the optical properties of silver nanoparticles. Journal of Nanoscience and Nanotechnology 4: 254-259

29. Jain, D., Kumar Daima, S., Kachhwaha, S and Kothari, S.L. (2009) Synthesis of plant mediated silver nanoparticles using Papaya Fruit Extract And Evaluation of their Antimicrobial Activities. Digest Journal of Nanomaterials and Biostructures, 4(3), 557-56.

30. Leela A. and Vivekanandan M, 2008. Tapping the unexploited plant resources for the synthesis of silver nanoparticles. African Journal of Biotechnology 7: 3162-3165.

31. Mude N, Ingle A, Gade A, Rai M, 2009.Synthesis of silver nanoparticles using callus extract of Carica papaya- A First Report. Journal of Plant Biochemistry and Biotechnology 18: 83-86.

32. Bar H, Bhui DK, Sahoo GP, Sarkar P, De SP, Misra A, 2009. Green synthesis of silver nanoparticles using latex of Jatropha curcas. Colloids and Surfaces A: Physicochemical and Engineering Aspects 339:134-139.

33. Gardea-Torresdey JL, Gomez E, Peralta-Videa JR, Parsons JG, Troiani H, Jose-Yacaman M, 2003. Alfalfa sprouts: a natural source for the synthesis of silver nanoparticles. Langmuir 19:1357-1361.

34. Shankar SS, Rai A, Ahmad A, Sastry M, 2004. Biosynthesis of silver and gold nanoparticles from extracts of different parts of the geranium plant. Applications in Nanotechnology 1: 69–77.

35. X.L. Ren and F.Q. Tang // Acta. Chim. Sinica.60 (2002) 393.

36. Geethalakshmi, R and Sarada, D.V.L. (2010) Synthesis of plant-mediated silvernanoparticles using Trianthema decandra extract and evaluation of their anti microbial activities. International Journal of Engineering Science and Technology, 2(5), 76-81.

37. David, E., Elumalai, EK., Prasad, T.N.V.K.V., Venkata Kambala and Nagajyothi, P.C. (2010) Green synthesis of silver nanoparticle using Euphorbia hirta L and their antifungal activities. Archives of Applied Science Research, 2(6), 76-81.

38. Parashar, V., Parashar, R., Sharma, B and Pandey, A. C. (2009) Parthenium leaf extract mediated synthesis of silver nanoparticles: a novel approach towards weed utilization. Digest Journal of Nanomaterials and Biostructures, 4, 45 -50.

39. Chandran SP, Chaudhary M, Pasricha R, Ahmad A, Sastry M, 2006. Nanotriangles and silver nanoparticles using Aloe vera plant extract Biotechnology Programme 22: 577-583.

40. Ankamwar B, Damle C, Ahmad A, Sastry M, 2005a. Biosynthesis of gold and silver nanoparticles using Emblica officinalis fruit extract, their phase transfer and transmetallation in an organic solution. Journal of Nanoscience and Nanotechnology 5: 1665-1671.

41. S. Prashanth, I.Menaka R.Muthezhilan, Navin Kumar Sharma (2011)Synthesis of plant-mediated silver nanoparticles using medicinal plant extract and evaluation of its anti microbial activities. International Journal of Engineering Science and Technology (IJEST) ISSN : 0975-5462 Vol. 3 No. 8 August 2011 6250.

42. Shankar SS, Rai A, Ahmad A, Sastry MJ, 2004. Rapid synthesis of Au, Ag, and bimetallic Au core–Ag shell nanoparticles using Neem (Azadirachta indica) leaf broth. Journal of Colloid and Interface Science 275: 496-502.

43. T. Klaus, R. Joerger, E. Olsson and C.G. Granqvist // Proc. Natl. Acad. Sci. USA 96 (1999) 13611.

44. D. Schuler and R.B. Frankel // Appl. Microbiol. Biotechnol. 52 (1999) 464.

45. B. Nair and T. Pradeep // Cryst. Growth. Des. 2 (2002) 293.

46. M. Lengke and G. Southam // Geochim. Cosmochim. Acta 70 (2006a) 3646.

47. F.U. Mouxing, L.I. Qingbiao, S.U.N. Daohua, L.U. Yinghua, H.E. Ning, D.E.N.G. Xu, WANG Huixuan and Jiale Huang // Chinese. J. Chem. Eng. 14(1) (2006)114.

48. A.R. Shahverdi,A. Fakhimi, H.R. Shahverdi and S.Minaian // Nanomedicine 3 (2007) 168.

49. Y. Konishi, K. Ohno, N. Saitoh, T. Nomura and S. Nagamine // Trans. Mater. Res. Soc. Jpn. 29 (2004) 2341.

50. R.P. Parikh, S. Singh, B.L.V. Prasad, M.S.Patole, M. Sastry and Y.S. Shouche // Chembiochem. 9 (2008) 1415.

51. K. Kalishwaralal, V. Deepak, S. Ramkumarpandian, H. Nellaiah and G. Sangiliyandi // Mater. Lett. 62 (2008) 4411.
52. R. Vaidyanathan, S. Gopalram, K. Kalishwaralal, V. Deepak, S. Ramkumarpandian and S. Gurunathan // Colloids. Surf. B. 75 (2010) 335.
53. K. Kalimuthu, R. Suresh babu, D. Venkataraman, Mohd Bilal and S. Gurunathan // Colloid. Surf. B. 65(2008) 150.
54. M.M. Ganesh Babu and P. Gunasekaran // Colloid. Surf. B. 74 (2009) 191.
55. S. Gurunathana, K. Kalimuthu, R. Vaidyanathana, V. Deepak, S. Ramkumarpandiana, J.Muniyandi, H. Nellaiah and Soo Hyun Eom // Colloids. Surf. B. 74 (2009) 328.
56. M. Kowshik, S. Ashtaputre, S. Kharrazi, W. Vogel, J. Urban and S.K. Kulkarni // Nanotechnol. 14 (2003) 95.
57. P. Mukherjee, A. Ahmad, D. Mandal, S. Senapati, S.R. Sainkar and M.I. Khan // Angew. Chem. Int. Ed. 40 (2000) 3585.
58. J.C. Chen, Z.H. Lin and X.X. Ma // Lett. Appl. Microbiol. 37 (2003) 105.
59. K.C Bhainsa and S.F.D'souza //Colloids. Surf. B. 47 (2006) 160.
60. P. Mukherjee, M. Roy, B. Mandal, G. Dey and J. Ghatak // Nanotechnol. 19 (2008) 75103.
61. N. Vigneshwaran, A.A. Kathe, P.V. Varadarajan, R.P. Nachane and R.H. Balasubramanya // Colloids. Surf. B. 53 (2006) 55.
62. D.S. Balaji, S. Basavaraja, R. Deshpande, D. BedreMahesh, B.K. Prabhakara and A. Venkataraman // Colloids. Surf. B. 68 (2009) 88.
63. Z. Sadowski, I.H. Maliszewska, B. Grochowalska, I. Polowczyk and T. Kozlecki // Mater. Sci. Poland. 26 (2008)419.
64. N.S. Shaligram, M. Bule, R. Bhambure, R.S. Singhal, K. Sudheer Kumar Singh, George Szakacs and Ashok Pandey // Process. Biochem. 44 (2009) 939.
65. G. Thirumurugan, S.M. Shaheedha andM.D. Dhanaraju // I.J. ChemTech Research. 1 (2009) 714.
66. M. Karbasian, S.M. Atyabi, S.D. Siadat, S.B. Momen and D. Norouzian // Am. J. Agric. Biological Sci. 3 (2008) 433.
67. Daizy Philip // Spectrochimica. Acta. A. 73 (2009) 374
68. Govindraju, K., Kiruthiga, V., Ganesh Kumar, V and Singaravelu, G. (2009), Extracellular synthesis of silver nanoparticles by a marine alga, Sargassum wightii Grevilli and their antibacterial effects. Journal of Nanoscience and Nanotechnology, 9, 5497 - 5501.
69. Sharma NC, Sahi SV, Nath S, Parsons JG, Gardea-Torresdey JL, Pal T, 2007. Synthesis of plant-mediated gold nanoparticles and catalytic role of biomatrix-embedded nanomaterials. Environmental Science and Technology 41: 5137-5142.
70. Rai M,Yadav A, Gade A, 2009. Silver nanoparticles as a new generation of antimicrobials. Biotechnology Advances 27: 76-83.
71. Rai M, Yadav A, Gade A, 2008. Current trends in photosynthesis of metal nanoparticles Critical Reviews in Biotechnology 28: 277-284.
72. Deplanche K and Macaskie LE, 2008. Biorecovery of gold by Escherichia coli and Desulfovibrio desulfuricans. Biotechnology and Bioengineering 99: 1055-1064.
73. Sanghi R. and Verma P, 2009. Biomimetic synthesis and characterisation of protein capped silver nanoparticles. Bioresource technology 100: 501-504.