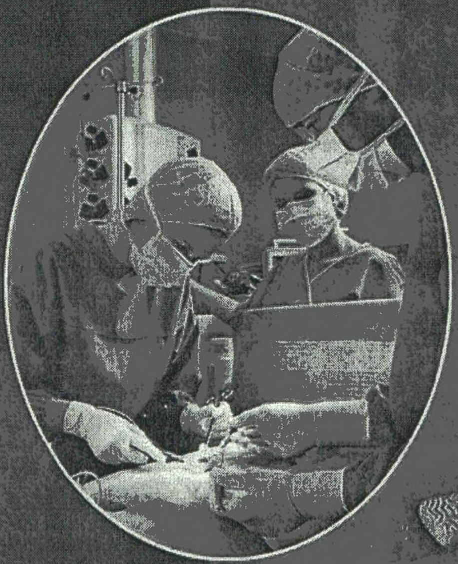
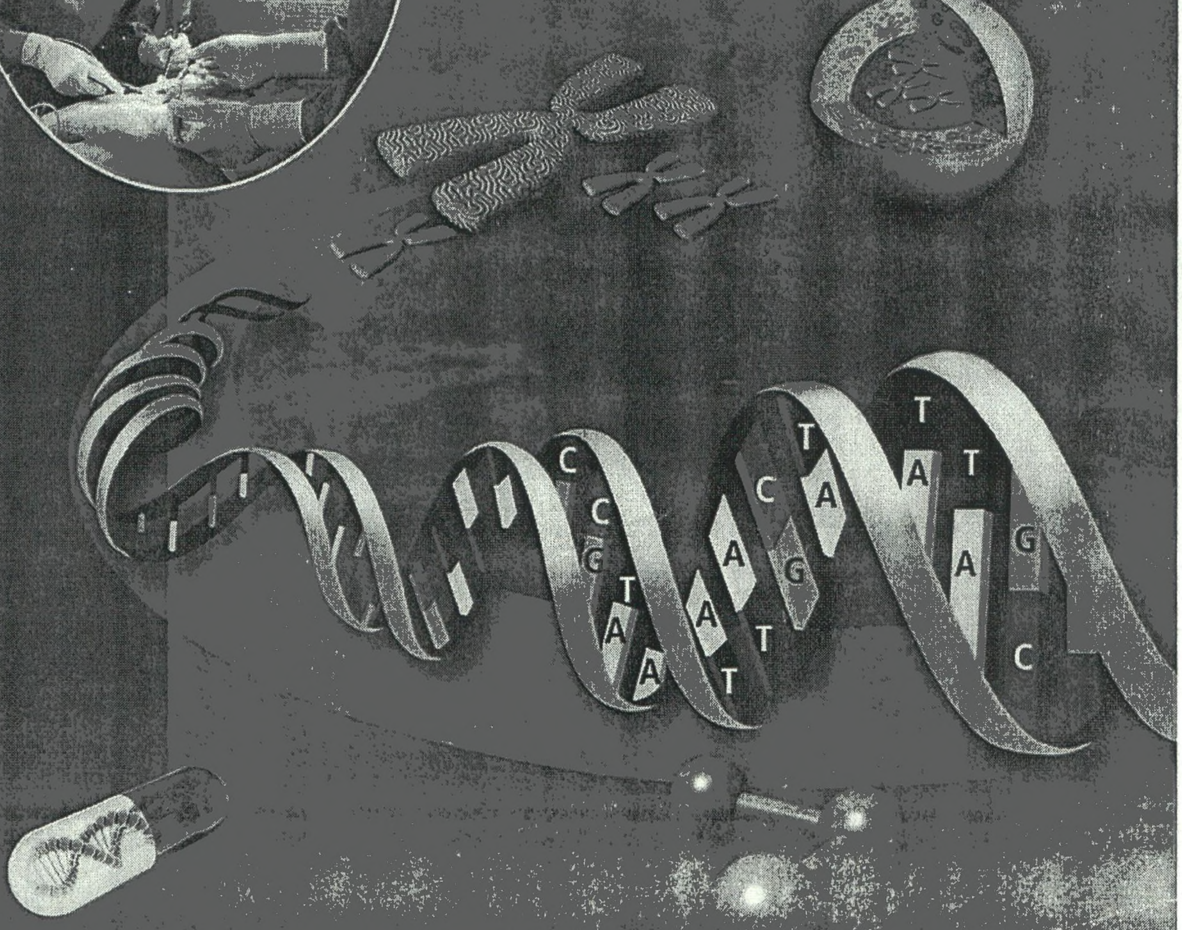
ISSN 2278 - 5221
Vol. 1, No. 1, July 2012

International Journal of Pharma Medicine and Biological Sciences

IJPMBS





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Int. J. Pharm. Med. & Bio. Sc. 2012

International Journal of Pharma Medicine and Biological Sciences

ISSN 2278 – 5221 www.ijlbpr.com
Vol. 1, No. 1, July 2012

Review Article

GREEN SYNTHESIS OF SILVER NANOPARTICLES

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Traditionally nanoparticles were produced only by physical and chemical methods. Often, chemical synthesis method leads to presence of some of the toxic chemical absorbed on the surface that may have adverse effect in the medical applications. This is not an issue when it comes to biosynthesized nanoparticles via green synthesis route .So, in the search of cheaper pathways for nanoparticles synthesis, scientist used microbial enzymes and plant extracts (phytochemicals). With their antioxidant or reducing properties they are usually responsible for the reduction of metal compounds into their respective nanoparticles. Biological methods of synthesis have thus paved way for the "greener synthesis" of nanoparticles and these have proven to be better methods due to slower kinetics. Green synthesis provides advancement over chemical and physical method as it is cost effective, environment friendly, easily scaled up for large scale synthesis.

Keywords: Nanoparticles, Plant extracts, Green synthesis.

INTRODUCTION

In India, food borne diseases occur frequently there by causing higher morbidity and mortality rate. WHO estimates that 25% of the total 57 million annual deaths that occur worldwide are caused by microbes and this proportion is significantly higher in developing countries. India has a burgeoning urban population of over 1 million which is projected to increase by 15.5% in 2025. With the increase in urban population density, emerging and re-emerging food borne and water-borne diseases caused by multi-resistant pathogenic organisms constitute a major threat in India. Antimicrobial resistance is a major factor in virtually all infections and poses serious public health problems. These concerns have led to major research effort to discover alternative strategies for the treatment of bacterial infections. Hence, researchers are searching for "new antimicrobial agents" preferably as nanoparticles (Manonmani and Juliet, 2011).

Nanotechnology is a reliable and enabling environment friendly process for the synthesis of nanoscale particles of structures ranging from approximately 1-100 nm(British Standards Institute, 2007; and SCENIHR, 2008). Nanosize results in specific physicochemical characteristics such as high surface area to volume ratio, which

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potentially results in high reactivity (Peijnenburg *et al*, 2009).

TYPES OF NANOPARTICLES

Nanoparticles can be broadly grouped into two,namely, organic nanopartilces which include carbon nanoparticles (fullerness) while, some of the inorganic nanoparticles include magnetic nanoparticles, noble metal nanoparticles (like gold and silver) and semi-conductor nanoparticles (like titanium oxide and zinc oxide). There is a growing interest in inorganic nanoparticles i.e of noble metal nanoparticles (Gold and silver) as they provide superior material properties with functional versatility. Due to their size features and advantages over available chemical imaging drug agents and drugs, inorganic particles have been examined as potential tools for medical imaging as well as for treating diseases. Inorganic nanomaterials have been widely used for cellular delivery due to their versatile features like wide availability, rich functionality, good compatibility, and capability of targeted drug delivery and controlled release of drugs (Xu *et al.*, 2006).

METHODS FOR NANOPARTICLE SYNTHESIS

Traditionally nanoparticles were produced only by physical and chemical methods. Some of the commonly used physical and chemical methods are ion sputtering, solvothermal synthesis, reduction and sol gel technique. Basically, there are two approaches for nanoparticle synthesis namely the bottom- Up and top Down approach. In the top down approach, scientists try to formulate nanoparticles using larger ones to direct their assembly. The bottom-up approach is a process that builds towards larger and more complex system by starting at the molecular level and maintaining precise control of molecular structures.

NEED FOR GREEN SYNTHESIS

Biosynthesis of nanoparticles is a kind of bottom-up approach where the main reaction occurring is reduction/oxidation. The need for biosynthesis of nanoparticles rose as the physical and chemical processes were costly. Often, chemical synthesis method leads to presence of some of the toxic chemical absorbed on the surface that may have adverse effect in the medical applications (Parashar *et al.*, 2009).This is not an issue when it comes to biosynthesized nanoparticles via green synthesis route (Begum *et al.*, 2009).So, in the search of cheaper pathways for nanoparticles synthesis, scientist used microbial enzymes and plant extracts (phytochemicals). With their antioxidant or reducing properties they are usually responsible for the reduction of metal compounds into 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(Forough *et al.*, 2010).

BENEFITS OF GREEN SYNTHESIS OF NANOPARTICLES

Biological methods of synthesis have thus paved way for the "greener synthesis" of nanoparticles and these have proven to be better methods due to slower kinetics (Elumalai *et al.,* 2010). They offer better manipulation, control over crystal growth and their stabilization. This has motivated an upsurge in research on the synthetic routes that allows better control of shape and size for various nanotechnological applications. The use of environmentally beningn materials like plant extracts (Jain et al., 2009),bacteria (Saifuddin *et al.*, 2009), fungi (Bhainsa *et al.*, 2006) and enzymes (Willner *et al.*, 2007) for the synthesis of silver nanoparticles offer numerous benefits of eco-friendly and compatibility for pharmaceutical and other biomedical applications as they do not use toxic chemicals for the synthesis protocol. A number of approaches are available for the synthesis of silver nanoparticles namely reduction in solutions, chemical and photochemical reactions in reverse micelles, thermal decomposition of silver compounds, radiation assisted, electrochemical, sono-chemical, microwave assisted process and recently via green chemistry route (Begum *et al.*, 2009).

NANOSILVER

One of the substances used in nanoformulation is silver (nanosilver). Due to its antimicrobial properties, silver has also been incorporated in filters to purify drinking water and clean swimming pool water (Agency for Toxic Substances and Diseases Registry—ATSDR, 1990 cited in WHO, 2002). To generate nano-silver, metallic silver has been engineered into ultrafine particles by several methods; include spark discharging, electrochemical reduction, solution irradiation and cryo- chemical synthesis (Chen and Schluesener, 2008). Nano-silver particles are mostly smaller than 100 nm and consist of about 20-15,000 silver atoms (Oberdorster *et al.*, Warheit *et al.,* 2007 cited in Chen and Schluesener, 2008). In addition, nanostructures can be produced as tubes, wires, multifactes or films. At the nano-scale, the silver particles exhibit deviating physico-chemical properties (like pH dependent partitioning to solid and dissolved particulate matters) and biological activites compared with the regular metal (Lok *et al.,* and Pal *et al.*, 2007).This is due to the higher surface area per mass, allowing a larger amount of atoms to interact with their surroundings.

Due to the properties of silver at the nanoscale, nanosilver is nowadays used in an increasing number of consumer and medical products. Because, silver is a soft white lustrous element, an important use of silver nanoparticles is to give a products a silver finish. Still, the remarkably strong antimicrobial activity is the major direction for development of nano-silver products. Examples are food packaging materials and food supplements, odour-resistant textiles, electronics, household appliances, cosmetics and medical advices, water disinfectants and room sprays.

PROPERTIES OF SILVER

Silver is one of the basic element that makes up our planet. It is a rare, but naturally occurring element, slightly harder than gold and very ductile and malleable. Pure silver has the highest electrical and thermal conductivity of all metals and has the lowest contact resistance (Nordberg and Gerhardsson, 1988). Silver can be present in four different oxidation states: Ag^0, Ag^{2+}, Ag^{3+}. The former two are the most abundant ones, the latter are unstable in the aquatic environment (Smith and Carson, 1977 cited in WHO, 2002). Metallic silver itself is insoluble in water, but metallic salts such as $AgNO_3$ and Silver chloride are soluble in water (WHO,2002).Metallic silver is used for the surgical prosthesis and splints, fungicides and coinage. Soluble silver compounds such as silver slats, have been used in treating mental illness, epilepsy, nicotine addition, gastroenteritis and infectious diseases including syphilis and gonorrhea (Marshall and Schneider, 1977; Shelley *et al,* 1987; Gulbranson *et al.,* 2000).

Although acute toxicity of silver in the environment is dependent on the availability of free silver ions, investigations have shown that these concentrations of Ag+ ions are too low to lead toxicity (WHO, 2002). Metallic silver appears to pose minimal risk to health, whereas soluble silver compounds are more readily absorbed and have the potential to produce adverse effects (Drake and Hazelwood, 2005). The wide variety of uses of silver allows exposure through various routes of entry into the body. Ingestion is the primary route for entry for silver compounds and colloidal silver proteins. Dietary intake of silver is estimated at 70-90µg/day. Since silver in any form is not thought to be toxic to the immune , cardiovascular, nervous or reproductive system an it is not considered to be carcinogenic (Furst and Schlauder, 1978), therefore silver is relatively non-toxic(Chen and Schluesener 2008). Silver demand will likely to rise as silver find new uses, particularly in textiles, plastics and medical industries, changing the pattern of silver emission as these technologies and products diffuse through the global economy (Eckelman and Graedel 2007).

MODE OF ACTION OF NANO-SILVER

Nano-silver has biological properties which are significant for consumer products, food technology (ex-food processing equipments, packaging materials food storage), textile /fabrics (ex-antimicrobial clothing) and medical applications (ex-wound care products, implantable medical advices). In addition, nanosilver has unique optical and physical properties that are claimed to have a great potential for medical applications (ex-diagnostics, drug delivery and imaging.

1. Anti Bacterial Properties

Nanosilver is an effective killing agent against a broad spectrum of Gram negative and Gram positive bacteria (Burrell *et al,* 1999; Yin *et al.,* 1999) including antibiotic resistant strains (Wright *et al.,* 1998, Percival *et al.,* 2007). Gram negative bacteria include genera such as *Acinetobacter, E. coli, Pseudomonas, Salmonella, Vibrio* and Gram positive bacteria includes many well known genera such *as Bacillus, Clostridium, Enterococus, Listeria, Staphylococcus* and *Streptococcus.* Small nanoparticles with a larger surface area to volume ratio provide a more efficient means for antibacterial activity even at a very low concentration. Silver nanoparticles are of different shapes (spherical, rod-shaped, truncated, triangular nanoplates) were developed by synthetic routes. Truncated triangular silver nanoplates were found to display the strongest anti-bacterial activity could be due to their larger surface area to volume ratios and their crystallographic surface structures.

2. Anti Fungal Properties

Nanosilver is an effective and a fast-acting fungicide against a broad spectrum of common fungi including genera such as *Aspergillus, Candida* and *Saccharomyces* (Wright *et al,* 1999).

3. Antiviral Properties

Silver nanoparticles (diameter 5-20 nm, average diameter 10 nm) inhibit HIV -1 (Sun *et al.,* 2005). An interesting observation was that gold nanoparticles (average diameter10 nm) showed relatively a low anti HIV 1 activity (6-20% when compared to silver nanoparticles of 98% (Elechiguerra *et al.*, 2005).

4. Anti-inflammatory Properties

In animal models, nanosilver alters the expression of matrix metallo-proteinases (proteolytic enzymes that are important in various inflammatory and repair processes) (Kiirsner *et al.*, 2001) suppresses the expression of tumor necrosis factor (TNF-α), interleukin (IL)-12 and IL 1β and induces apoptosis of inflammatory cells (Bhol and Schechter; 2005 and 2007).

ANTIBACTERIAL MODE OF ACTION

Recently, Hwang and Colleagues (2008) performed a study on stress-specific bioluminescent bacteria, based on which they propose a synergistic toxic effect of the silver nanoparticles and the silver ions that they produce. These ions move into the cells and leads to the production of reactive oxygen species. Furthermore, because of the membrane damage caused by nanoparticles, the cells cannot effectively extrude the silver ions and limit their effect. Based on the greater tendency of silver ions to strongly interact with thiolgroups of vital enzymes and phosphorus containing bases (Hatchett and White 1996) and on the presence of silver nanoparticles inside the cells(Morones *et al.*, 2005) it is likely that further damages could be caused by interactions with compounds such as DNA. This interaction may prevent cell division and DNA replication from occurring and also ultimately leads to cell death. However, no DNA damage was found by Hwang *et al.* (2008). Evidence has been obtained by suggesting that silver nanoparticles may modulate the phosphotyrosine profile of putative bacterial peptides that could affect the cellular signaling and therefore inhibit the growth of bacteria (Shrivastava *et al.*, 2007).

To gain more insight in the human exposure to nanosilver an inventory has been made of products containing nanosilver. Three major product categories included are food, consumer products and medical products.

CONCLUSION

The Green chemistry synthetic route can be employed for both silver and gold silver nanoparticles synthesis. Among the silver nanoparticles, the biological organisms such as bacteria, fungi and yeast or several plant biomass or plant extracts have been used for nanoparticle synthesis used for a number of applications from electronics and catalysis to biology, pharmaceutical, medical diagnosis and therapy. Therefore, field of nanotechnology is still in its infancy and more research needs to be focused on the mechanistic of nanoparticle formation which may lead to the fine tuning of the process ultimately leading to the synthesis of nanoparticles with a strict control over the size and shape parameters.

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ISSN 2278-5221