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Silver nanoparticles and its potential applications: A review

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Abstract
Silver nanoparticles have gained major interest because of their wide potential applications. Silver nanoparticles cause less toxicity to human health but, highly toxic to microorganisms. Due to this, silver nanoparticles have found good applications in biomedical, antimicrobial, catalysis, human health and environmental remediation etc. Silver nanoparticles are extensively used for biomedical applications due to the antimicrobials, bio-detection and labelling, bio-magnetic separations, drug delivery, imaging, bone cement, therapeutics etc. Silver nanoparticles as a result of their excellent optical and electronic properties are promising catalytic materials for various applications. Some applications are in automotive catalyst, membranes, fuel cells, photocatalysts, propellants, scratch-resistant coatings, structural ceramics and solar cells, organic dyes degradation and chemo-catalytic reduction of 4-nitrophenol (4-NP) to 4-aminophenol (4-AP).
Silver nanoparticles also have applications in protection of human health. They are used in sun protection lotions, lipsticks, skin creams, UV protection ointment and creams and toothpaste in the cosmetics industry. The applications of silver nanoparticles can also be exploited in the environmental bioremediation. Silver nanoparticles are found to be very effective in air disinfection, water disinfection, surface disinfection etc. This makes it very useful in environmental treatment. Thus silver nanoparticles can be considered as good for having wide range of applications for the human benefits. This review article covers all the applications of silver nanoparticles which are found to be very essential in research activities, bioremediation, and very effective in making the human life good, easy and safe.

Keywords: silver nanoparticles, application, biomedical, catalysis, environmental remediation

Introduction
Nanotechnology could be a quickly increasing field and has been probably utilized in a large variety of economic product worldwide. Over the last few years, the engineering and scientific community has been visualizing remarkable progress in the field of Nano science and technology (Rajput *et al*., 2017) [55, 57]. Nanotechnology deals with the study of nanoparticles having a size range of 1-100 nm. Nanoparticles are of nice interest, thanks to their extraordinarily tiny size and huge surface to volume quantitative relation that results in each chemical and physical variations in their properties compared to bulk of identical chemical composition, like mechanical, biological and sterical properties, chemical action activity, thermal and electrical conduction, optical absorption and freezing point (Daniel, 2004) [16].
These particles even have several applications in numerous fields like medical imaging, nano-composites, filters, drug delivery, and physiological state of tumors (Lee *et al*., 2008; Tan *et al*., 2006) [43, 66] (Fig 1). Silver nanoparticles have drawn the eye of researchers owing to their in-depth applications in areas like integrated circuits (Kasthuri *et al*., 2009; Kotthaus *et al*., 1997) [35], sensors (Kotthaus *et al*., 1997), biolabelling, filters, antimicrobial toiletries fibres (Zhang *et al*., 2003) [74], cell electrodes (Klausi-Joerger *et al*., 2001), cheap paper batteries (silver nano-wires) (Hong *et al*., 2006) [29] and antimicrobials (Cho *et al*., 2005; Duran *et al*., 2007) [11, 19].

Biomedical Applications
Nanomaterials have a wide range of applications in antimicrobials, bio-detection and labelling, bio-magnetic separations, drug delivery, MRI contrast agents, Orthopedics/implants, sunscreens and thermal spray coatings (Sharma and Bhargava, 2013) [59]. Initial studies have urged that the acceleration of wound healing among the presence of nanoparticles is as a result of the reduction of native matrix metalloproteinase (MMP) activity and thus the rise in neutrophils cell death within the wound. It has been urged that the MMP can induce inflammation and thence cause non-healing wounds (Kirsner *et al*., 2001) [39]. A reduction in the amount of pro-inflammatory cytokines were put together incontestable in associate in a

nursing passing mouse model with burn injury once silver nanoparticles were introduced (Tian et al., 2007). These are some biomedical applications of silver nanoparticles (Fig. 2)

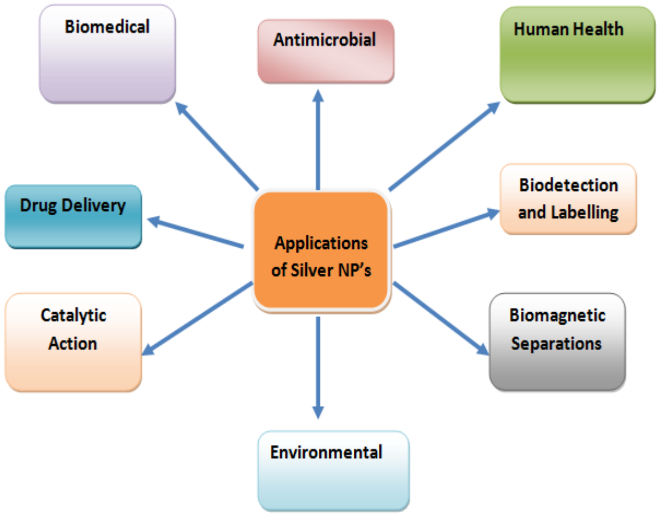

Fig 1: Applications of silver nanoparticles

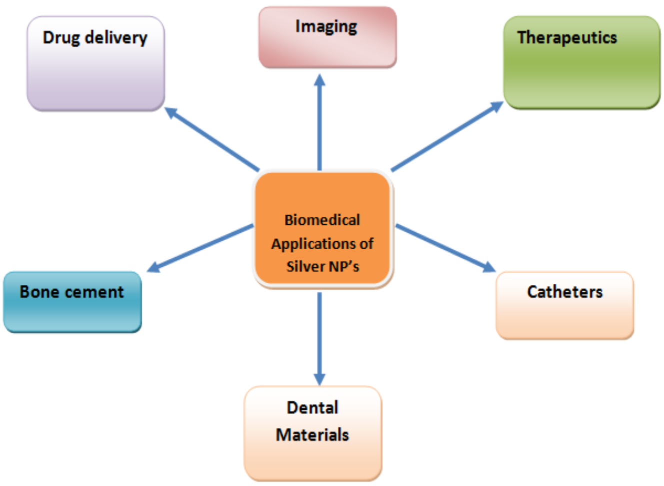

Fig 2: Biomedical applications of silver nanoparticles

Imaging

Nanoparticles in imaging applications have been increasingly developed in last 20 years (Choi and Wang, 2011) [12]. Silver nanoparticles possess many valuable optical properties that have opened the door to new approaches in sensing and imaging applications, offering a wide range of detection modes such as colorimetric, scattering, SERS (Surface Enhanced Raman Spectroscopy), and MEF (Metal Enhanced Fluorescence) techniques, at extremely low detection limits (Caro *et al*., 2010) [8]. Metal nanoparticles scatter light with their extinction spectra consist of a combination of both absorption and scattering (Kelly *et al*., 2002) [36]. These metal nanoparticles interact with the oscillating electromagnetic field of light and result in the collective coherent oscillation of the metal conduction electrons with respect to nanoparticle positive lattice. This process is resonant at a particular frequency and the name given is Localized Surface Plasmon Resonance.

Silver nanoparticles in therapeutics

Wound healing is a complex and multiple-step process involving the integration of activities of many different tissues and cell lineages (Martin P, 1997) [48]. Silver nanoparticles have the applications in wound healing. Acticoat is the first commercial wound dressing made up of two layers of polyamide ester membranes covered with silver nanoparticles (Reidy *et al*., 2013) [58]. Silver nanoparticles seem to promote the healing effect and give better cosmetic results. It is considered that silver nanoparticles assist the proliferation and migration of keratinocytes and reduce the formation of collagen by fibroblasts and modulate the number of cytokines produced (Wong *et al*., 2010).

It was reported that silver nanoparticles synthesized by fungus also exhibit wound healing effect. In an excision rat model, it was found that the extra-cellularly synthesized Ag NPs via fungus *Aspergillus niger* modulate the cytokines involved in wound healing (Kalaiselvan *et al*., 2009) [34]. In addition to this, silver nanoparticles are very effective fungicide as well as having antiviral properties (Galdiero *et al*., 2011) [23]. It was also reported that the silver nanoparticles dressing has a beneficial effect of protecting the wound site from bacterial contamination (Sibbald *et al*., 2007) [60]. Ag NPs hydrogel derived using *Arnebia nobilis* root extract was examined for wound healing effect in an animal model. The results concluded that AgNPs hydrogel has the positive antimicrobial potential and provided a novel approach for wound treatment (Garg *et al*., 2014) [25]. Taken together, silver nanoparticles use in the aspects of wound healing provides a novel therapeutic direction for wound treatment in clinical practices.

Silver impregnated catheters

The central venous catheter (CVC) is a commonly used device in managing acutely ill patients in the hospital. Much research has been conducted to make AgNP's coated catheters, because of antimicrobial potential of silver nanoparticles. A new generation of silver impregnated catheters has become available for clinical use. These catheters contain silver ions which are bonded with an inert ceramic zeolite. Silverline (Spiegelberg GmbH and Co. KG, Hamburg, Germany) and ON-Q Silver Soaker™ (I-Flow Corporation, CA, USA) are two commercially available medical catheters containing silver nanoparticles to prevent catheter-associated infections (Chaloupka *et al*., 2010) [9].

Bone Cement

In a research investigation, it was found that poly (methyl methacrylate) bone cement loaded with 1% silver nanoparticles completely inhibited the growth of *Staphylococcus epidermidis, methicillin-resistant S. epidermidis*, and *methicillin-resistant S. Aureus*. There was no major difference between the nanosilver loaded bone cement and the nontoxic control group in quantitative and qualitative cytotoxicity tests (Alt *et al*., 2004) [1]. Hence, the use of silver nanoparticles for bone cement is an effective replacement of antibiotics in orthopedic use.

Dental Materials

Silver nanoparticles also have some important applications in dental materials. A research report suggests that the effect of AgNPs incorporation to a composite resin at different concentrations have good mechanical properties and notable antimicrobial potential (Cheng *et al*., 2012) [10]. Yamamoto and his co-workers also showed that a resin composite containing silver ion-implanted filler exhibit a good antimicrobial effect on oral streptococci (Yamamoto *et al*., 1996) [72]. NSPs in endodontic filling materials provided a notably enhanced anti-bactericidal effect against *Streptococcus milleri*, *S. aureus*, and *Enterococcus faecalis* (Magalhaes *et al*., 2012) [47]

Other biomedical applications
Silver nanoparticles also have some applications in diagnosis and cancer treatment, cardiovascular implants, anti-inflammatory agents, contact lenses and in drug delivery by acting as drugs carrier (Liu *et al*., 2012, Tien *et al*., 2008, Skirtach *et al*., 2004) [46, 62, 69]. Local drug targeting has some disadvantages as it increases the local drug concentrations. That's why we need some more effective drug delivery strategies. Nanoparticles have specific particles as tools to enable these strategies. Because of their small size which allows penetration to cell membranes, binding and stabilization of proteins, and lysosomal release after endocytosis (De *et al*., 2008) [17].

In a research conducted by Benyettou and his co-workers, silver nanoparticles based drug delivery system was synthesized for the delivery of two anticancerous drugs doxorubicin (Dox) and alendronate (Ald) by coating AgNP with bisphosphonate alendronate (Ald). The unreacted primary ammonium group of Ald remained free and was then bonded with Rhodamine B (RhB), through amide formation, or Dox, through imine formation. The RhB-conjugated NPs (RhB–Ald@AgNPs) were studied in HeLa cell culture. They have found that Dox–Ald@AgNPs had notably greater anti-cancer activity *in vitro* than either Ald or Dox alone (Benyettou *et al*., 2015) [6]. It can be said that silver nanoparticles have very vast applications in drug delivery and must find out. In addition to this, silver nanoparticles can also be used in combination with vanadium oxide in battery cell components improving battery performance is one example of advanced silver nanotechnology, which can be used in making of next-generation active implantable medical devices (Etheridge *et al*., 2013) [20].

Catalytic action applications
Nanomaterials have a wide range of applications in automotive catalyst, membranes, fuel cells, photocatalysts, propellants, scratch-resistant coatings, structural ceramics and solar cells (Sharma and Bhargava, 2013) [59]. High surface area and high surface energy predetermine metal nanoparticles for being effective catalytic medium. The growing small silver particles have been proved to be more effective catalysts than stable colloidal particles. These growing particles catalysed the borohydride reduction of several organic dyes. As compared with the stable and larger silver particles, the rate of reduction catalysed by growing particles was found to be faster.

Catalysis is due to efficient particle-mediated electron transfer from the $BH4^-$ ion to the dye. The catalytic activity of the particles depends on their size, $E1/2$ of the dye, and the dye-particle interaction. By controlling the size of nanoparticles, its catalytic activity can be controlled, as the redox potential depends on the nanoparticle size (Jana *et al*., 2000) [31]. Using Kashayam and Guggulutiktham an ayurvedic medicine, the size-dependent catalytic activity of the synthesized AgNPs was observed in the reduction of methylene blue dye by using $NaBH_4$ (Suvith *et al*., 2014) [65]. The synthesized AgNPs from the plant extract of *Gloriosa superb* has the electron relay effect which influences the degradation of methylene blue at the end of the 30 min (Ashokkumar *et al*., 2013) [4]. The catalytic activities of Ag-NPs synthesized by *Dimocarpus longan* seed extract were assessed against the photocatalytic degradation of methylene blue and chemo-catalytic reduction of 4-nitrophenol (4-NP) to 4-aminophenol (4-AP). The results suggest that the prepared Ag-NPs have strong chemo-catalytic activity with a complete reduction of 4-NP to 4-AP within 10min (Khan *et al*., 2016) [38]. Hence, it can be said that silver nanoparticles find good applications in catalysis.

Human health applications
Nanoparticles have many different effects on human health relative to bulk material from which they are produced (Khan, 2014) [37]. Increase the biological activity of nanoparticles can be beneficial, detrimental or both. Many nanoparticles are small enough to have an access to the skin, lungs, and brain (Koziara *et al*., 2003; Oberdorster *et al*., 2005) [42, 51]. Exposure of metal containing nanoparticles to human lung epithelial cells generated reactive oxygen species, which lead to oxidative stress and damage to the cells (Limbach *et al*., 2007; Xi *et al*., 2006) [45, 71].

The biocompatibility and toxicity of silver nanoparticles were exhibited by observing single silver nanoparticle inside the embryos at each development stage. In zebra fish, the types of aberrations were strictly dependent on the dose of silver nanoparticles (Asharani *et al*., 2008) [3]. Nanomaterials are also used for sun protection, lipsticks, skin creams, UV protection ointment and creams and toothpaste in the cosmetics industry.

Environmental Applications
In automobile catalytic converters and power generation equipments, nanomaterials can be used as the catalysts to react with some noxious and toxic gases like carbon monoxide and nitrogen oxide to preclude the environmental pollution created from burning of gasoline and coal (Sharma and Bhargava, 2013) [59]. Silver nanoparticles are of great concern to wastewater treatment utilities and to biological systems (Jalandoni-Buan *et al*., 2015) [30]. These are major areas of environmental applications of silver nanoparticles (Fig. 3)

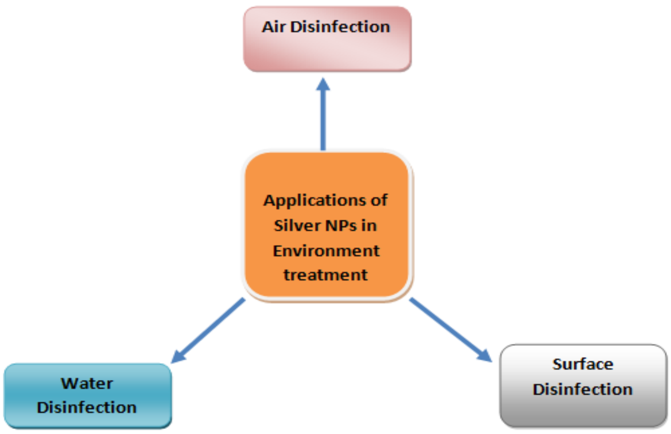

Fig 3: Applications of silver nanoparticles in environment treatment

Air Disinfection: Silver nanoparticles have broad applications in environmental treatment. Air contains many micro-organisms which are very harmful to us. Bioaerosols are the airborne particles of biological origins. These include viruses, bacteria, fungi, which are proficient of causing infectious and allergenic diseases. According to WHO report, 50% of the biological contamination present in indoor air comes from air-handling systems, and the formation of harmless micro-organisms such as bacterial and fungal pathogens was found in air filters. The mycotoxins produce by these pathogens are very dangerous to human health. But, development of silver nanoparticles based airfilters has reduced the problem of biological contamination to some extent. Activated carbon filters (ACF) were already examined for the effect of AgNP's on the elimination of bacterial contamination. The results display that silver nanoparticles based ACF filters were very effective for the removal of bioaerosols.

Jung AH and his co-workers generated a new Ag-coated CNT hybrid nanoparticles (Ag/CNTs) using aerosol nebulization and thermal evaporation/condensation processes and studied their applicability to antimicrobial air filtration (Jung *et al*., 2011) [33]. It was found that the antimicrobial filtration efficacy of Ag/CNTs was higher as compared with that of pure Ag-NPs. The explanation for this was concluded that surface area of Ag-NPs was enhanced by CNTs. The polypropylene based airfilters were also made with the addition of $AgNO_3$ as an antimicrobial agent. The results showed the reduction of biological contamination in airfilters. Clearly, silver nano-based filters find a good advantage in the removal of biological contamination in the air and the technology behind the antimicrobial filter treatment is very necessary for the future research.

Water Disinfection: Water is one of the most important substances for the survival of living beings on Earth. About 70% of the portion of the earth is covered with water, but only 0.6 % of water is suitable for human consumption. Due to this, safe drinking water is becoming an issue for the entire world. The report of WHO showed that at least 1 billion people do not have access to safe drinking water. Contamination of drinking water and the subsequent outbreak of waterborne diseases are the leading cause of death in many developing nations (Pradeep, 2009) [54]. To reduce this microbial contamination and waterborne diseases, there is an enormous need for treatments methods. A significant interest has arisen in the use of Ag-NPs for water disinfection.

The silver nanoparticles produce through the chemical process can be deposited onto the porous ceramic materials to form the Ag-NPs–porous ceramic composite by using 3-aminopropyltriethoxysilane (APTES) as a connecting molecule. The water filters made up of the Ag-NPs–porous ceramic composite was tested for sterilization property. It was found that at a flow rate of 0.01 l min^{-1}, the output count of *E. coli* was nil when the input water had a bacterial load of $\sim 10^5$ CFU ml^{-1} (Yakub *et al*., 2012) [73].

Similarly, the *chem*-Ag-NPs were effectively formed onto the macroporous methacrylic acid copolymer beads by chemical reduction method for disinfection of water (Gangadharan *et al*., 2010) [24]. The *chem*-Ag-NPs formed on these copolymer beads were stable during washing with water. This is because of the interaction of the *chem*-Ag-NPs with the $–COO^-$ carboxylic functional group on the copolymer beads. The *chem*-Ag-NPs were highly effective against all tested bacterial strains (*E. coli, P. Aeruginosa, B. subtilis, S. Aureus).*

Recently, researchers have reported that the colloidal Ag-NPs has the disinfectant ability for the treatment of gastrointestinal bacterial infections (Haider *et al*., 2015) [28] One of the other reported studies proposed that core-shell magnet nanoparticles comprised of Ag-NPs are effective disinfectant in water purification system (Chudasama *et al*., 2009) [13]. Hence, it can be said that silver nanoparticles have very much importance in water disinfection and controlling the water pollution to some level.

Surface Disinfection: Making of bacteriocidal coatings has increased the interest of researchers to protect the human health and the environment. Ag-NPs-embedded paints are of particular interest owing to their potential bactericidal activity. The environmentally friendly chemical approach to synthesize metal NPs-embedded paint, in a single step, from common household paint was investigated (Kumar *et al*., 2008) [32]. It was found that the surfaces coated with silver-nanoparticle containing paint showed a antimicrobial properties against both the gram-positive and gram negative human pathogens like *S. Aureus*, and *E. Coli.*

Silver nanoparticles can also be used in the preservation of food material or increasing the shelf life of food material by avoiding microbial growth. Ag-NPs-coated paper could be useful for preventing microbial growth for longer periods in food preservation. Gottesman and his co-workers described a simple method to develop coating of colloidal silver on paper using ultrasonic radiation, called the sonochemical coating (Gottesman *et al*., 2011) [27]. It was concluded from the research that AgNPs coated paper has the potential application as packing material in the food industry.

Also, silver nanoparticles can be used in the fabrication of silver impregnated scrub suits worn by healthcare workers. The antimicrobial effect of silver impregnated scrub suits used in a veterinary hospital was investigated by Freeman and his co-workers (Freeman *et al*., 2012) [22].

Though silver nanoparticles are very obliging in environment treatment, but still it has some environmental risk issues too. In a research investigation, the environmental risk of silver nanoparticles was checked by determining the released silver from commercial clothing. The sock material and wash water contained silver nanoparticles of 10-500 nm diameter.

Antimicrobial Applications

Silver is being used from centuries as a non-toxic, safe inorganic antibacterial agent capable of killing about 650 microorganisms that cause various diseases (Annamalai and Nallamuthu, 2016) [2]. It has a significant potential for a wide range of biological application such as antibacterial agents for antibiotic resistant bacteria, preventing infections, healing wounds and anti-inflammatory (Atiyeh *et al*., 2007) [5].

Silver ions and the compounds made from it have a very strong destructive effect on many bacterial species and also have low toxicity towards animal cells. Therefore, silver ions, being an antibacterial component, are employed in the formulation of dental resin composites, bone cement, ion exchange fibres and coatings for medical devices (Panacek *et al*., 2006; Alt *et al*., 2004) [1, 53].

Silver nanoparticles also have antimicrobial properties. It was reported that Ag in nanoforms is considered less toxic than Ag^+ ions (Pattabi *et al*., 2013) [52] The antimicrobial properties of silver nanoparticles caused the employment of those nano-metals in numerous fields of medication, numerous industries, agriculture, packaging, accessories, cosmetics, health and military (Cho *et al*., 2005; Duran *et al*., 2007) [11, 19].

Silver nanoparticles with their large surface to volume ratio have been widely studied as a valuable material for their strong antimicrobial effect (Song *et al*., 2012) [64]. The toxicity of silver nanoparticles has been well-known to a wide range of microorganisms. The antibacterial property of silver nanoparticles against *Staphyloccocus aureus*, *Pseudomonas aeruginosa* and *Escherichia coli* has been investigated (Birla *et al*., 2009) [7]. It was considered that silver nanoparticles of 1 -10 nm range attach to the surface of the cell membrane and disturb its proper function like permeability and respiration (Morones *et al*., 2005) [49]. The biosynthesized silver nanoparticles displayed antimicrobial activity against a range of pathogenic microorganisms, such as *C. albicans*, *V. parahaemolyticus*, *S. enterica*, *B. anthracis*, *B. cereus*, and *E. coli* (Singh *et al*., 2015) [61]. The Green rapid biogenic synthesis was demonstrated by silver nanoparticles using aqueous extracts of leaves of *Cupressus torulosa* D.Don leaf extract and $AgNO_3$. Antimicrobial activity of the synthesized AgNP's from the leaf extracts of *C. torulosa D*.Don and fungal endophytes *Pestalotiopsis versicolo* was done against three pathogenic bacteria *Bacillus subtilis, Salmonella entrica* and *Pseudomonas aeruginosa* showed promising medicinal drug activity against all the pathogens (Rajput *et al*., 2016; Rajput *et al*., 2017) [55, 56, 57].

The exact mechanism of antimicrobial action is not clearly known, but studies suggest that silver nanoparticles have the ability to damage the cell membrane permeability, damage the respiration functions of the cell, and encourage the formation of free radicals. The antimicrobial activity of silver nanoparticles was investigated by using fluorescent bacteria (Gogoi *et al*., 2006) [26]. A different conclusion was drawn from the study that silver nanoparticles get attached to the sulfur containing bacterial cell which causes the death of the bacteria. The fluorescent measurements of the cell-free supernatant reflected the effect of silver on recombination of bacteria.

Several studies have shown that the combination of silver nanoparticles with antibiotics leads to an enhanced effect of the antibiotics against microorganisms (Fayaz *et al*., 2010) [21]. This is probably due to the increase in cell wall penetration by antibiotics with the nanoparticles. The synergistic effect of the antibiotics (vancomycin, novobiocin lincomycin, oleandomycin, penicillin G, and rifampicin) in association with biosynthesized silver nanoparticles increased the sensitivity of the tested microorganisms (*S. enterica*, *E. coli*, *V. parahaemolyticus*, *B. anthracis*, and *B. Cereus* (Singh *et al*., 2015) [61]. *S. enterica*, *E. coli*, and *V. parahaemolyticus* observed in this study was highest for novobiocin (4.82 fold), then for lincomycin, oleandomycin, and rifampicin (4.23 fold), then for vancomycin (3.98 fold), and finally for penicillin G (3.66 fold). Many researchers have demonstrated the synergistic effect of biosynthesized silver nanoparticles with commercially available antibiotics (Dar *et al*., 2013; Fayaz *et al*., 2010; Naqvi *et al*., 2013) [15, 21, 50]. However, the exact mechanism behind this activity is still not well understood and must be explored.

Other important applications

Silver NP's shows the wide application in the bone as in mesenchymal stem cells, osteoclast and Osteoblast for cell labelling, drug delivery and gene delivery (Tautzenberger *et al*., 2012) [67] (Fig 4). Metal nanoparticles have some unique chemical, optical and magnetic properties because of their size, shape, and composition which can be exploited for the applications. New biosensors have been developed with a new approach by making gold- silver alloy nanoparticles. This gives the advantage of the ease of derivatization of gold nanoparticles and the enhanced surface plasmon resonance extinction coefficient of silver nanoparticles.

Silver nanoparticles, due to its enhanced surface plasmon resonance extinction coefficient are alternate candidates as labels to bio-detection of DNA, RNA, proteins etc. Hence, silver nanoparticles have good application in molecular diagnostic (Dias, 2009) [14]

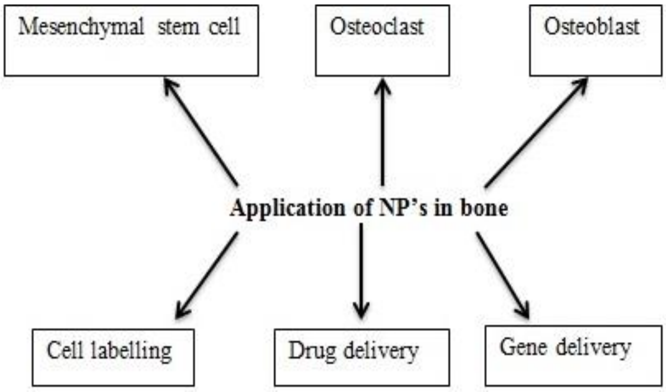

Fig 4: Overview of nanoparticles applications in bone

In a research conducted by Kyle and his co-workers, Silver nanoparticles were modified with self-assembled monolayers of hydroxyl-terminated long chain thiols and these were encapsulated in a silica shell. These encapsulated core–shell nanoparticles were then used for cell labelling and analyzed by flow cytometry and microscopy.Use of core-shell AgNPs as optical labels exhibited two orders of magnitude enhancement of the scattering intensity compared with unlabeled cells (Dukes *et al*., 2014) [18]. Hence, AgNP's have wide applications in biotection and cell labelling and these applications must be explored.

Metal nanoparticles have been used in biomagnetic separations also. In a recent research by Li and his co-workers, Fe_3O_4@Cu-apatite NPs were synthesized via a facile hydrothermal method and used to magnetically separate histidine tagged proteins directly from the mixture of lysed cells. Cu $^{(2+)}$ on the surface toward histidine tags have high affinity to histidine tagged proteins. Results indicated that the Fe_3O_4@Cu-apatite NPs offered high protein binding ability with negligible nonspecific protein adsorption (Li *et al*., 2016) [44]. Hence, this new era of research must be explored in order to find some more applications of silver nanoparticles in biomagnetic separations.

Conclusion

Nanotechnology deals with the nanoparticles having a size of 1-100 nm. Biological synthesis showed the good capability to the synthesis of silver nanoparticles. From the technological point of view, the silver nanoparticles have wide potential applications in the biomedical field, healthcare, environmental bioremediation, medical and pharmaceutical applications. Silver nanoparticles are also found to be very effective catalysts. They have the ability to degrade textile dyes. The catalytic activity can be controlled by controlling the size of the nanoparticles.

Silver nanoparticles show variable applications so that these can be used in advanced portable gadgets and also can be used in the production of cloths, leather items, and coating because silver nanoparticles can protect these items from the attack of various harmful microorganisms. Thus, use of silver nanoparticles is a cost-effective, less time consuming and we can explore the other hidden applications of silver nanoparticles.

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