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Therapeutic Properties of Nanosilver Particles

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Nanomaterial and nanoparticles are defined as particles that have at least one dimension in the range of 1 to 100 nm. They have special physicochemical properties by virtue of their small size (Buzea *et al.*, 2007). The surface effects and quantum effects of nanoparticles were reported to have great potential for medical applications.

Antibacterial properties

Nanosilver was reported to be effective against a broad spectrum of Gram-negative and Gram-positive bacteria, including antibiotic-resistant strains. Gram-negative bacteria include genera such as *Acinetobacter*, *Escherichia*, *Pseudomonas*, *Salmonella*, and *Vibrio*. Gram-positive bacteria include many well-known genera such as *Bacillus*, *Clostridium*, *Enterococcus*, *Listeria*, *Staphylococcus*, and *Streptococcus*. Antibiotic-resistant bacteria include strains such as methicillin-resistant and vancomycin-resistant *Staphylococcus aureus*, and *Enterococcus faecium*. Further, silver nanoparticles are also known to enhance the antibacterial activity of various antibiotics. The antibacterial activities of penicillin G, amoxicillin, erythromycin, clindamycin, and vancomycin against *Staphylococcus aureus* and *Escherichia coli* increase in the presence of silver nanoparticles. Size-dependent (diameter 1-450 nm) antimicrobial activity of silver nanoparticles has been reported with Gram-negative and Gram-positive bacteria.

In addition to size and concentration, shape-dependent antimicrobial activity of silver nanoparticles has been reported against Gram-negative bacteria.Truncated triangular silver nanoplates display the strongest antibacterial activity. Spherical silver nanoparticles with

{111} facets attach directly to the bacterial surface of the cell membrane and are translocated inside bacteria.

2.1.2 Anti-fungal properties

Nanosilver is an effective, fast acting fungicide against a broad spectrum of common fungi including genera such as *Aspergillus, Candida* and *Saccharomyces* . The possible mechanism was reported to be similar to that of the antibacterial actions. Silver nanoparticles (diameter 13.5 nm) were found to be effective against yeast isolated from bovine mastitis. It was also reported that nanosilver may exert an antifungal activity by disrupting the structure of the cell membrane and inhibiting the normal budding process due to the destruction of the membrane integrity. It was reported that the antifungal activity of fluconazole and itraconazole were enhanced against the tested pathogenic fungi in the presence of Silver nanoparticles and confirmed by the increase in fold area of inhibition. Xu *et al*., (2013) investigated the *in vitro* activity of nanosilver versus those of amphotericin B against 37 pulmonary aspergillosis isolates and found that the activity of nanosilver against *Aspergillus* species was superior and two times greater than that of amphotericin B.

2.1.3 Antiviral properties

Silver nanoparticles (diameter 5-20 nm) inhibit HIV-1 virus replication. Size dependant antiviral activity of silver nanoparticles has been shown with HIV-1 virus and interaction of silver nanoparticles with HIV-1 virus was exclusively within the range of 1-10 nm. Trefry and Wooley (2012) evaluated the antiviral activity of 25-nm silver nanoparticles (AgNPs) against an HIV-1-based, pseudotyped virus particle engineered to encode antibiotic resistance. The AgNPs showed a half maximal inhibitory concentration against the virus with no significant toxicity against the host cells. It was reported that silver nanoparticles exhibited remarkable inhibitory effects on adenovirus type 3 *in vitro*, which suggested that silver nanoparticles could be a potential antiviral agent for inhibiting adenovirus type-3 infection.

Anti-biofilm properties

Nanosilver inhibits the formation of biofilms. Biofilms are complex communities of surface attached aggregates of microorganisms embedded in a self-secreted extracellular polysaccharide matrix. Biofilm forming bacteria act as efficient barriers against antimicrobial agents and the host immune system, resulting in a persistent colonization and / or infection at the site of the biofilm formation. Kalishwaralal *et al*., (2010) reported that biologically synthesized silver nanoparticles exhibited a potential anti-biofilm activity *in vitro,* on biofilms formed by *Pseudomonas aeruginosa* and *Staphylococcus epidermidis* and there was more

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than 95% inhibition in biofilm formation and recommended therapeutic application of silver nanoparticles in the treatment of microbial keratitis.

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