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Multidrug-Resistant Bacteria are no Match for Silver Nanoparticles, a Potent Nanoweapon

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ABSTRACT

Resistance to various drugs has become a growing problem for pharmaceutical and biomedical businesses (MDR). infectious microbes When germs become resistant to antibiotics or are able to reproduce in unfavorable environments, they are more likely to reappear. Multidrug-resistant illnesses need expensive, long-term treatment in addition to increasing mortality and morbidity. Antimicrobial agents must be created, modified, or discovered as a result of this.

An significant research goal is to identify MDR-killing compounds. Silver has been used in various compounds and bhasmas for thousands of years. It has been used in Ayurveda for a long time as a bactericide. The use of silver nanoparticles may help combat antibiotic-resistant microorganisms. It has been shown that silver nanoparticles can kill MDR bacteria. A system that can be put to a variety of different uses. Patients who are no longer able to take their current prescriptions may benefit from nanotechnology-based drugs. microbes.

KEYWORDS: *Antibiotic-resistant Staphylococcus aureusaureus may be killed using silver nanoparticles.*

INTRODUCTION

Drug-resistant human illnesses provide a significant challenge to the pharmaceutical and biomedical businesses. Creatures that feed on the remains of other organisms (Tenover 2006). A person is at danger if they get infected with the virus. The treatment of sickness caused by MDR microorganisms is notoriously challenging. Thus, the patient's stay in the hospital will be extended as well. Antibiotics with a wide range of activity are required for multi-drug therapy, but they are less effective, dangerous, and expensive (Webb et al. 2005). In this way, new antibacterial compounds have been produced or improved. One of the key goals of this research is to understand how bacteria function. Considering the current state of affairs (Humberto et al. 2010). In the creation of metal nanoparticle contrast agents for biomedical imaging and diagnostics, biomarker identification, cell labeling, and nanodrug delivery systems, nanotechnology serves as a strong base. Duran (2008, Singh and Singh, 2019) and Sing and Singh (2019) (2011) In light of this, scholars are now doing more research. nanoparticles of silver as well

Nanoparticles may be able to alleviate the problem of MDR bacteria resurfacing in the therapy process (Gemmell et al. 2006). It has been known since the dawn of time that silver has antimicrobial qualities. Because of new antibiotics and silver's therapeutic properties, antimicrobial usage has declined.

One such possibility is Schluesener (2008). Silver's antibacterial characteristics may be utilised in a wide range of applications. A billionth of a meter is all it takes to shrink them. Silver nanoparticles have undergone physiochemical modifications in the battle against bacteria. Unique chemistry or physics is produced by objects with a small volume but a big surface area (Kim et al.) There is some recent evidence to show that silver nanoparticles may be an effective antibacterial agent against drug-resistant microbes, even those that are resistant to numerous medications. E. coli, an ampicillin-resistant Pseudomonas strain, and other bacteria may help combat MDR microorganisms. Bacteria and fungi are resistant to the methicillin antibiotic. Silver nanoparticles and nanoweapons are examples of nanotechnology. Multiple drug resistance in Staphylococcus aureus bacteria; vancomycinaureus-resistant Staphylococci Mahendra K. Rai, an employee of the department of communication. It is becoming more challenging for those who are MDR (multidrug resistant). infectious microbes Microorganisms that are resistant to many antibiotics are becoming more common. Antibiotic resistance and growth in challenging environments are essential for the survival of microorganisms. It has been shown that treating infections caused by MDR bacteria results in increased mortality, morbidity, and expense. Since then, efforts to develop antimicrobials that are effective against MDR

bacteria have gained popularity. "Bhasmas and silver-based compounds have been found." This is what the author says. As a bactericidal remedy, it has been utilized for millennia in Ayurveda. Antibiotic-resistant bacteria may benefit from the usage of silver nanoparticles. According to this review, silver nanoparticles have been found to be bactericidal for MDR bacteria.

Silver-Based Antimicrobials: Prehistorical, Historical and Contemporary Status

Even though silver is a more common metal than gold, it's considerably more malleable and ductile, and it also any metal (Susan et al. 2009). Cutlery, jewelry, dental alloys, photographic paper money, and monetary coins all used to be made of silver in ancient times (Chen and Schluesener 2008). Before this time, there were no antibiotics. For a long time, open wounds and burns have been treated using silver's antibacterial properties (Moyer et al. 1965). In the past, they were fully aware of it. Antibacterial properties of silver Silver ions are particularly reactive, which causes them to attach to proteins and disrupt the bacterial cell's structure.

Breach of the cytoplasmic and nuclear membranes results in cell death. According to Castellano and coworkers, silver ions may disrupt the replication of bacterial DNA (2007; Landsdown 2002). DNA condensation and cell death are the results of protein thiol group reactions with silver ions (Feng et al. 2000). Feng's and his colleagues' findings (2000).

Nitrosamine, an Element Found in Silver (AgNO3)

People who aren't acquainted with the word "Lunar caustic," more often known in the United States as silver nitrate, will refer to it as Lapis infernalis (Latin for "Lunar caustic") instead (French). STIs, salivary gland fistulas, and infections of the perianal and bone areas were all treated with silver nitrate in the 1700s (Landsdown 2002). Treatment with silver nitrate was prevalent in the nineteenth and early twentieth centuries. A chemical substance was involved. In certain cases, silver nitrate may have accelerated epithelialization and crust formation in burn victims (Castellano et al. 2007). The silver nitrate eye was first made available to the general public in 1881. Carl S. F. Crede utilized drops to treat ophthalmia. Throughout his career, B. Crede created silver-impregnated neonatorums (Landsdown 2002). With the application of silver nitrate drops in water, Neisseria gonorrhoeae spread was curtailed in the year 1884. (SilvestryRodriguez et al. 2007). There is a powdered silver nitrate with a purity level of 0% available. According to legend, this remedy was used to treat wounds. This solution has antimicrobial characteristics. Neither E. coli nor Pseudomonas bacteria are implicated here. As you may have heard, Clifton (1970).

Antioxidant: Sulfadiazine of Silver (AgSD)

Sulfadiazine is an effective broad-spectrum bactericide that may be applied to the skin in a water-soluble cream form. It is most often used to treat burns. Adhesion of this material causes harm to the cytoplasmic membrane and other cellular components. Transcriptional repression by DNA base pair binding (Maple and colleagues). It happened in 1992. Please consult McDonnell and Russell for further details (1999). Cream was used to treat burns caused by a substance that included silver sulfadiazine. In the investigation of E. coli, S. aureus, and Klebsiella, Staph aureus and Klebsiella were also demonstrated to have substantial antibacterial activity.

Zeolite, silvery in colour

Silver zeolite is formed when alkaline minerals interact. The ion exchange procedure may be used to produce silver ions from metal and crystal aluminosilicate. In Japan, silver zeolite-coated antibacterial ceramics are popular. Safeguards for food, medical equipment, and other items. (Kawahara and coworkers, l99) Two possible mechanisms of action for silver zeoli have been proposed, one by Matsumura and colleagues in their 2003 research, the other by Matsumura et al. Silver ions, found in silver zeolite, kill bacteria when they come into touch with it.

NANOPARTICLES

Nanoparticles of Silver

Warheit et al. estimate that 10,000 to 15,000 silver atoms are present in silver nanoparticles with a diameter less than 100 nanometers. Using particle engineering, silver may be reduced to an ultrafine powder. Spark discharges, electrochemical reduction, solution irradiation, and the production of cryochemicals are all examples of physical processes (Chen and Schluesener 2008). Also being investigated are methods ranging from the chemical to the biological. To begin, silver nanoparticles must be prepared. It's a trait that sets silver nanoparticles apart from other metals: they're small. The pH-dependent partitioning of solids to liquid has an effect on particle size and biological activity. As a millennia-old technique, silver nanoparticles may be found in a slew of applications. The unusual chemistry and physics of these substances have shown their antibacterial capabilities. Members of the Kim team and others Silver nanoparticles provide the following health benefits:

They're Quite Powerful in Killing Germs

Aspergillusniger, Saccharomyces cerevisiae and Candida albicans are quickly killed by this mold inactivator (Percival et al., 2007). 5–10 nm wide silver nanoparticles. Beyond 20 nanometers, the HIV-1 virus is incapable of replication. Humberto and his coworkers at work serve as an excellent instance of this (2010). To counteract the effects of inflammation, proteinases help in the creation of proteins, reduce inflammation, and aid in the repair of injured tissue.

Examples of anti-inflammatory cytokines that target cells in the body that cause inflammation include TNF, IL-12, and IL1. Silver nanoparticles have been linked to a variety of functions, including wound healing, cytokine control, and inhibiting biofilm development.

Silver Nanoparticles

There are several methods to get antimicrobials. Several studies suggest that silver nanoparticles may be an effective therapy for germs that are resistant to antibiotics (Table 1). Antibacterial therapies are increasingly using silver nanoparticles (Rai et al. 2009). In this work, silver nanoparticles were shown to have antibacterial characteristics. Using silver ions, Feng et al. found that Staph aureus and E. coli could be killed by a silver ion. According to Sondi and Salopek, silver nanoparticles may be able to destroy the Gram-negative bacteria E. coli (2007). Because of their interaction with bacterial cell membrane components, silver nanoparticles may be carcinogenic, according to one research. TEM, EDX, LDI, and TOF MS tests have all indicated that silver ions kill E. coli. Silver ions have also been found to have an antimicrobial effect. In LDI studies, the positive benefits of silver ions have been proven (MALDI-TOF MS). The ribosomal subunit protein, it turns out, is affected by silver ions in a broad spectrum of enzymes (Yamanaka et al. 2005).

Nanoparticles have been exposed to inert gas condensation and co-condensation methods for the aim of testing against E. coli. (2005). The nanoparticles found E. coli to be cytotoxic. In 2005, Morones and his colleagues used silver nanoparticles to effectively treat Gram-negative E. coli bacteria. Bacteria in the mid-log phase of cell growth were destroyed by silver nanoparticle concentrations more than 75 lg/ml (Kim et al. 2007). De'Souza tested the antibacterial properties of silver water dispersion solution using 29 antibacterial agents (15-nm-diameter silver nanoparticle clusters containing silver ions produced by an electrocolloidal silver process). Amoxicillin and clindamycin were effective against Staph aureus, Shigellaflexneri, Salmonella typhi, and Bacillus subtilis. Amoxicillin was shown to have anti-MRSA properties when mixed with the silver-water dispersion. (2006) Coworkers of De Souza. A study by Duran and colleagues (2007a) found that silver nanoparticles embedded in textile fibers may function as antibacterial agents (2007a). Silver nanoparticle-coated cotton demonstrated to be an effective antibacterial textile in laboratory tests. Silver nanoparticles in polyvinyl alcohol nanofibres have the ability to restrict the development of E. coli and Staph aureus. They've been shown to be effective bandages in clinical testing (Jun et al. 2007). In 2007, Shahverdi et al. conducted research on silver nanoparticles. Klebsiella bacteria were used to make this silver nanoparticle.

Table 1 Activity of silver nanoparticles against broad spectrum of bacteria

S. No.	Different forms of silver	Target organisms	References
1.	Silver ions	*Staphylococcus aureus* and *Escherichia coli*	Feng *et al.* (2000)
2.	Silver nitrate	Periodontal pathogens	Spacciapoli *et al.* (2001)
3.	Silver zeolite	*E. coli*	Matsumura *et al.* (2003)
4.	Silver nanoparticles	*E. coli*	Sondi and Salopek (2007) Pal *et al.* (2007)
5.	Silver ions	RNA viruses	Butkus *et al.* (2004)
6.	Silver nanoparticles	*E. coli*, *Vibrio cholerae*, *Pseudomonas aeruginosa* and *Salmonella typhus*	Morones *et al.* (2005)
7.	Silver nanoparticles	*E. coli* in liquid and solid medium	Baker *et al.* (2005)
8.	Silver ions	*E. coli*	Yamanaka *et al.* (2005)
9.	Silver nanoparticles	*Staph. aureus* and *E. coli*	Shahverdi *et al.* (2007)
10.	Super paramagnetic silver nanoparticles, bifunctional Fe_2O_4, @Ag nanoparticles	*E. coli*, *Bacillus subtilis* and *Staphylococcus epidermidis*	Gong *et al.* (2007)
11.	Nanofibres impregnated silver nanoparticles	*E. coli* and *Staph. aureus*	Jun *et al.* (2007)
12.	Silver nanoparticles on cotton Fabrics	*Staph. aureus*	Duran *et al.* (2007)
13.	Silver nanoparticles impregnated on the wound dressing	*E. coli* and *Staph. aureus*	Maneerung *et al.* (2008)
14.	Silver nanoparticles	*E. coli*, *Salmonella typhi*, *Staphylococcus epidermidis Staph. aureus*	Ingle *et al.* (2008)
15.	Silver nanoparticles	*Phoma glomerata*, *Phoma herbarum*, *Fusarium semitectum*, *Trichoderma* sp. and *Candida albicans*	Gajbhiye *et al.* (2009)
16.	Silver nanoparticles	*E. coli*, *Staph. aureus* and *Ps. aeruginosa*	Birla *et al.* (2009)
17.	Silver nanoparticles	*E. coli* and *Staph. aureus*	Gade *et al.* (2010)
18.	Silver nanoparticles	*E. coli* and *Ps. aeruginosa*	Geethalakshmi and Sarada (2010)
19.	Silver nanoparticles	*E. coli*, *Staph. aureus* and *Ps. aeruginosa*	Bonde *et al.* (2011)
20.	Silver nanoparticles	*Ps. aeruginosa*, *Staph. aureus*, pathogenic fungi *Aspergillus flavus* and *Aspergillus niger*	Govindaraju *et al.* (2010)
21.	Silver nanoparticles	*Staph. aureus*, *E. coli*, *Klebsiella pneumoniae*, *B. subtilis*, *Enterococcus faecalis*, *Ps. aeruginosa*	Namasivayam *et al.* (2011)
22.	Silver nanoparticles coated medical devices	*Staph. aureus* and *Streptococcus mutans*	Ki-Young (2011)
23.	Bacterial cellulose-silver nanoparticles composite	*E. coli* and *Staph. aureus*	Hernane *et al.* (2011)

Staph aureus was destroyed in mice when amoxicillin and other medicines were combined. Staph. aureus was effectively treated with erythromycin and silver nanoparticles (Shahverdi et al. 2007). Fusariumacuminatum silver nanoparticles were used to screen for the presence of pathogens such as E. coli and Salmonella in food. The study also looked at Staphylococcus epidermidis. Some of Ingle's previous employees and close acquaintances (2008). Mycogenic silver nanoparticles are 1–2 times more effective in killing germs than ionic silver. E. coli came in last place, followed by Staph. typhi and Salm. typhi. According to studies, silver nanoparticles coated with biological cellulose are inefficient against E. coli and Staph aureus (2008).

Using extracellular silver nanoparticles derived from Phomaglomerata,Birlaandcolleaguesperformedexperiments on E. coli, Staph. Because of its environmentally friendly biogenesis, silver nanoparticles are a feasible approach for combating bacterial antimicrobial resistance. Gajbhiye et al. produced extracellular silver nanoparticles for the first time in 2009 using Alternariaalternata. Silver nanoparticles may destroy a broad variety of microorganisms (Table 1). This isn't a problem since silver may be obtained in a variety of forms. An animal whose presence is desired in order to accomplish a certain objective. References Staphylococcus

aureus and Escherichia coli may be treated with silver ions in certain circumstances. 2. (1999, 2000, Feng and coworkers). Periodontal disease may be treated with silver nitrate, according to research published in 2000. This group also includes their coworkers. (2000) (2001) In contrast, the silver-zeolite E. coli is a last point. The study by Matsumura and coworkers (2003) Nanoparticles of silver Salopek and Sondi (2008) (2007) Coworkers and friends These examples were based on data from the year 2007. (2007) RNA viruses and silver ions It was in 2004 when the findings of Butkus et al. (2004) microorganisms such as E. coli, salmonella typhus, vibrio cholerae and pseudomonas are all resistant to silver nanoparticle treatment. Other than Morones, Our solar system's calendar was established in 2005. With the aid of silver nanoparticles, Yamanaka and colleagues' (2005) infection of E. coli with silver ions by Baker and colleagues. Staph aureus infected with silver nanoparticles Fe3O4 and @Ag nanoparticles by Shahverdi and colleagues just a few years ago in 2005: a study of Staph epidermidis infected with silver nanoparticles Fe3O4 and @Ag nanoparticles In a 2007 study, Gong and his colleagues used silver nanoparticle-impregnated nanofibres to treat E. coli and Staph. aureus. Silver nanoparticle-coated cotton fabric may allow Staph. aureus to grow, according to recent study by Jun et al.

Coli and Staph aureus bacteria Gade and his colleagues used silver nanoparticles to treat E. coli and P. aeruginosa in a clinical study in 2010. Bonde et al. (2011) studied 19-silver nanoparticle-exposed Aspergillusflavus, Aspergillusniger, Pseudomonas aeruginosa, Staphylococcus aureus, and dangerous fungi. Govindaraju and his colleagues have a good relationship (2010) Staph, E. coli, Klebsiellapneumoniae, and B. subtilis have all been shown to be resistant to silver nanoparticle therapy. (2011) S. aureus and Streptococcus mutans-fighting medical devices coated with silver nanoparticles (2011) 23. When the bacterium Staph. aureus was added to the solution, it created a silver nanoparticle composite. Silver nanoparticles with anti-MDR properties, in conjunction with Hernane (2011)

Crobiology 112 has 841-852 pages (841-4852). (2012) The annual meeting of the Society for Applied Microbiology was held in 2012. The writers in this case. Fungicidal properties of fluconazole and nanoparticles were investigated. When it came to antifungal action, fluconazole combined with silver nanoparticles performed better than fluconazole alone against Candida albicans. Silver nanoparticles were shown to have a significant antibacterial effect when used in combination with commonly prescribed medications. Indian curry leaf extract, Murrayakoenigii, contains silver nanoparticles with antibacterial efficacy against dangerous bacteria including E. coli, S. aureus, and Pseudomonas, as well as commercially available medications, according to research (Bonde et al. 2012). They observed that E. coli was killed four times faster when silver nanoparticles and gentamycin were employed combined. The combination of silver nanoparticles with tetracycline has been proven to be particularly effective against Staph. aureus, which is resistant to most antibiotics (216). Electrochemically produced polyamide-hydroxyurethane-based silver nanoparticles have recently been examined for their antibacterial characteristics in the laboratory (Stefan et al. 2011).

The disc diffusion method was used to examine E. coli and Staph. aureus for its antibacterial activity.. Silver nanoparticles having a diameter of 23 nm and a concentration of 5 lg/ml may kill Staph aureus. According to a research published in 2011, silver nanoparticles covered medical equipment decreased bacterial adhesion and the subsequent development of biofilms. For example, silver nanoparticles may be utilized to coat the device and kill germs over time. Silver nanoparticles and tissue conditioner were used to study Staphylococcus aureus, Streptococcus mutans, and Candida albicans in the lab. When combined with tissue conditioner, silver nanoparticles and Strep. aureus proved to be bactericidal. More than 1% silver nanoparticles had no effect on the viability of the cells studied. Candida albicans was shown to be killed by silver nanoparticles in a tissue conditioner. Only 20% of the CFUs were more than this threshold. Candida glabrata, Fusarium species, and others.

According to Namasivayam and colleagues' investigation, the SariumOxysporum (SaO) bacteria was responsible for the majority of the spores (2011). When exposed to silver nanoparticles with these bacteria, antibiotics failed to kill Staph aureus, E. coli, and Klebsiellapneumoniae. The researchers' silver nanoparticles had a significant antibacterial impact that surprised them much (Table 1).

Using Silver Nanoparticles to Combat Germs that are Resistant to Many Drugs

Drug-Resistant Bacteria

Bacteria might have developed resistance to antibiotics before Sir Alexander Fleming's 1929 discovery and use of penicillin. Academics and scientists are having a harder time combating antibiotic resistance. Antibiotic resistance has risen alarmingly as a result of the increasing use of antibiotics, insecticides, and other related compounds in agriculture. According to the Institute of Food Technology in England, bacteria and their progeny are considered drug resistant if they are able to live and flourish in conditions that normally kill them or restrict their development. As Abraham and Chain (1940) warned, antibiotic use might result in the development of resistance and the spread of antibiotic-resistant mutant strains throughout the natural environment. Several enzymes have been identified as being involved with drug resistance. When medications do not kill bacteria, but rather change their cell structure or metabolism, antibiotic-resistant bacteria may be formed. Bacterial resistance might develop as a result of repeated contact with antibiotics. A combination of genetic mutation, material change, and the acquisition of new genetic material

may result in a resistant species. During the processes of transduction, transformation, or conjugation, bacteria may pass on their acquired resistance either vertically (to progeny) or horizontally (to surrounding bacteria). Anti-MDR bacterial activity of silver nanoparticles in 2012 was discovered. There were 841–852 articles published in 2012 in the Applied Microbiology Journal. It's been 85 years since Applied Microbiology was established.

Antimicrobial Activity Mechanisms and Resistance Mechanisms

In order for antimicrobial drugs to be really effective, they must be able to target just the parasite and not the host. Antibiotics that target bacteria's particular architectural characteristics and metabolic activities rather than the host cell would be ideal. Alterations in the antimicrobial agent's action site may contribute to bacterial antimicrobial resistance (Cebrian et al. 2003; Biyela et al. 2004). Types, mechanisms of action, and patterns of antimicrobial resistance are all included in Table 2.

Multidrug-Resistant Bacteria may be Killed by Silver Nanoparticles

Antibacterial therapies often make use of silver nanoparticles. These medications may be able to treat multidrug resistant bacteria. Silver nanoparticles were studied by Panacek et al. to combat MRSA and other MDR infections (2006). Gram-positive and gram-negative bacteria may be killed by colloidal silver nanoparticles. Regardless of how resistant the bacteria in question are to antibiotics, silver nanoparticle antibacterial treatments are successful, according to Percival et al. Gram-negative bacteria such as Acinetobacter, E. coli, Paramecium, and Salmonella are also included in this genus. Bacillus, Clostridium, Enterococcus, Listeria, Staphylococcus, and Streptococcus are all Gram-positive bacteria. By limiting the formation of biofilms in bacteria and the human immune system, antibiotic-resistant bacteria such as MRSA and VRSA may be avoided from developing. Antibacterial activity of MRSA and other microbes was tested using silver nanoparticles with a diameter of 100 nm in LB broth (Ayala-Nunez et al. 2009). Silver nanoparticles were able to destroy both MRSA and non-MRSA microorganisms when supplied in varying amounts.

105 CFU inoculum suppressed the growth of both MRSA and non-MRSA at doses more than 135 mg ml1.

Silver nanoparticles may be used to treat dental cavities, according to new study by Espinosa-Cristobal et al (2009). These silver nanoparticles have been shown to be efficient in the eradication of bacteria and viruses. Silver nanoparticles are more effective in killing Strep mutans bacteria as they become smaller, according to scientific principles. Nanda and Saravanan were the first to discover the silver nanoparticles produced by Staphylococcus aureus (2009). Staph. epidermidis, Strep. pyogenes, Salmonella typhi, and Klebsiellapneumoniae were all studied using silver nanoparticles resistant to methicillin. Second on the list was a Staph. aureus strain that was resistant to methicillin.

Table 2 Mechanisms of action and resistance of major categories of antimicrobial agents

Antimicrobial group with examples	Mode of action	Mechanism of resistance	References
1. Beta-lactams monobactams, cephalosporins, carbapenems	Inhibit petidoglycan layer synthesis of cell wall	Production of Beta lactamase to destroy the Beta-lactams	Poole (2004)
2. Aminoglycosides streptomycin, kanamycin, tobramycin, gentamicin	Inhibit bacterial protein synthesis by binding 30S ribosomal subunits	Antibiotic inactivation by plasmid- and transposon encoded modifying enzymes	Kotra *et al.* (2000)
3. Phenicols chloramphenicol florfenicol	Binds reversibly to the teptidyltransferase component of the 50S ribosomal subunit prevent the transpeptidation of peptide chain elongation	Acquisition of plasmids encoding chloramphenicol acetyltransferases (CAT) and which enzymatically inactivate the drug	Falagas *et al.* (2008)
4. Sulfonamides and trimethoprim prontosil, gantrisin, erythromycin-sulfisoxazole	Act competitively inhibiting bacterial modification of para-aminobenzoic acid into dihydrofolate thus interfering with folic acid metabolism	Owing to acquisition of plasmid that encode a drug-resistant dihydropteroate	Chopra (2007)
5. Tetracycline chlortetracycline oxytetracycline, demeclocycline, doxycycline	Binds reversibly to the 30S ribosomal subunits, which blocks the access of aminoacyl t-RNA to the RNA-ribosome complex, to prevent bacterial polypeptide synthesis	Chromosomal mutations affecting outer membrane permeability	Chopra (2007) Falagas *et al.* (2008)
6. Quinolones/fluoroquinolones nalidixic acid	The target is DNA gyrase, essential enzyme for DNA replication	Target gene mutation and removal by efflux pumps	Hooper (2000) Falagas *et al.* (2008)

Epidermidis outperformed K. pneumoniae and S. typhi in terms of activity. MRSA and MRSE, two drug-resistant bacteria, were successfully treated using antimicrobial silver nanoparticles. When it came to activity, MRSE was the most active, whereas MRSA was the most active Drug-resistant bacteria including erythromycin-resistant Strep pyogene and ampicillin-resistant E. coli, as well as multidrug-resistant P. aeruginosa, were examined for their antibacterial efficacy against strains of E. coli and Streptococcus, as well as strains of these two organisms. Concentrations ranging from 30 to 100 mmol/l1 of silver nanoparticle therapy have been shown to be beneficial (Humberto et al. 2010). Nanoparticles 5–10 nm in size were shown to be effective in the treatment of Staph. aureus, MSSA, and MRSA. These pathogens were treated with colloidal silver nanoparticles that ranged in size from 20–45 nanometers, and were diluted in a broth solution to kill them using a broth microdilution procedure (Lkhagvajav et al. 2011). Table 3 shows that silver nanoparticles destroy MDR bacteria.

Antibacterials' Mechanisms of Action

The cell membranes of Gram-positive and Gram-negative organisms are distinct, having varying composition and structure. Peptidoglycans are present outside of the cytoplasmic membrane in the cell wall of these animals. Gram-negative bacteria and Gram-positive bacteria have very distinct outer membranes. Gram-negative bacteria, on the other hand, have a peptidoglycan layer that is just 2 to 3 nm thick. As of yet, the antibacterial capabilities of nanoparticles made up of silver are unknown.

The permeability of cells may be increased by adjustments to the membrane's structure, according to some research. A cell dies when the cytoplasmic membrane loses control of intracellular transport (Morones et al. 2005; Sondi and Salopek-Sondi 2007). Silver nanoparticles' ability to fight infections may be affected by the presence of reactive oxygen species (ROS) (Kim et al. 2007). When silver nanoparticles engage with enzyme thiol groups and phosphorus-based bases, it was hypothesized that these interactions might cause damage to DNA and other materials, according to Morones and colleagues (2005b). Due to DNA replication, cells may not be able to divide, leading to their demise. No evidence of DNA damage was found throughout the course of the examinations (Hwang et al. 2008).

If bacterial cell signaling is disturbed, reduced growth rates may be the outcome (Shrivastava et al. 2008). Hwang et al. discovered that sulfur nanoparticles and silver ions functioned together synergistically in bioluminescent bacteria (2008). Reactive oxygen species are produced when ions enter cells. Because nanoparticles have disrupted the cell membrane, silver ions can no longer be removed from cells (Hwang et al. 2008). According to Morones and colleagues, silver nanoparticles adhered to the membranes of Gram-negative bacteria, entered the cell, and released silver ions (2005). Silver nanoparticles, for example, may influence biological processes and antibiotic action, according to these studies. Acinetobacter, Escherichia, and Pseudomonos bacteria may also be killed by silver nanoparticles, along with Salmonella and Vibrio septicaemiae bacteria (MRE). In a biofilm, a polysaccharide extracellular matrix is created by microorganisms attached to each other on the surface. A biofilm is created to keep bacteria and antibiotics out of human bodies. Silver nanoparticles have been shown in studies to inhibit the growth of biofilms (Percival et al. 2007). Nanoparticles, the smallest units of silver, are used to describe these nanoparticles.

Bacterial cells may have dormant proteins that inhibit the organism from multiplying. Sulfhydryl groups in enzymes are destroyed by silver atoms (SHs). Cell membrane S-Ag connections between silver and thiol groups are crucial for energy and ion transport across the cell membrane. Intricately designed compounds and elements. Silver and oxygen react with thiolhydrogens in the cell, forming a disulfide bond (R-S-S-R). Silver aided enzyme disulfide links, which alter enzyme structure and function. MalK, FBPadolase, and the 30S ribosomal subunit of the ribosome are all affected by this drug. According to certain theories, silver ions may also have an effect on the 30S ribosomal subunit. Coenzyme succinyl phosphate After exposure to Ag+87, A synthase activity reduced. Because proteins are involved in several biological processes, toxic silver nanoparticles may kill pathogens and cause cell death (Yamanaka et al. 2005). Nanoparticles of silver bind to DNA bases containing both purine and pyrimidine nucleotides (2000). Base pairs prevented hydrogen bonding from forming between DNA's two antiparallel strands (Klueh et al. 2000). Figure 1 shows the diverse actions of silver nanoparticles on bacteria.

The antibacterial capabilities of silver nanoparticles are influenced by a number of different circumstances.

Size

Due to their small size, microparticles have unique characteristics and reactivity that cannot be found in bulk materials. Smaller particles with a higher surface area to volume ratio may be more efficient in killing bacteria. Silver nanoparticle electrical conductivity is inversely proportional to particle size. As a result of their larger surface area, nanoparticles are more likely to interact with bacteria. Bacteria are more likely to interact with nanoparticles with a diameter of less than 10 nm because of their increased reactivity. Small-sized silver nanoparticles are highly effective antibacterial agents (Morones et al. 2005; Raimondi et al. 2005). Nanoparticles with a diameter of 25 nm had the best correlation with bactericidal activity, according to Panacek et al (2006).

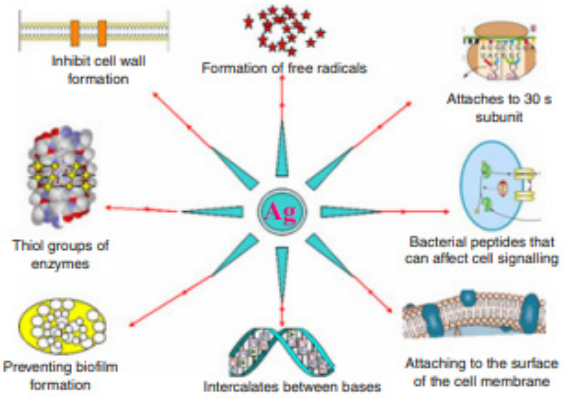

Figure 1 Silver nanoparticles showing multiple bactericidal actions.

Shape

Nanoparticles of varied shapes and sizes may have an impact on their ability to prevent bacterial growth, according to an examination of their ability to inhibit bacterial growth (Morones et al. 2005). Many studies have shown citrate-reduced spherical, rodenticular, and triangular citrate nanoparticles efficient against E. coli at different dosages. Triangular nanoparticles outperformed cylindrical ones, which outperformed rod-shaped nanoparticles, in terms of performance (Pal et al. 2007). Additionally, silver nanoparticles' antibacterial capabilities are influenced by their structure.

Concentration

It was discovered by Morones and his colleagues in 2005 that silver nanoparticles with a diameter of 1–100 nanometers were bactericidal for the Gram-negative bacterium E. coli, according to the journal Nanotechnology. They used a silver concentration of 75 lg/ml to test the optical density (OD) of 595 nm bacteria and found no significant growth1 (Morones et al. 2005).

Dose

Gram negative and Positive bacteria were studied for gene expression and dose-dependent effects.. In contrast to Gram-positive bacteria, silver nanoparticles exhibited antibacterial activity against Gram-negative bacteria. The dose was shown to have a significant influence on this result (Shrivastava et al. 2008).

CONCLUSIONS

Human antibiotic resistance has led to an increase in MDR illnesses and parasites. Broad-spectrum antibiotics need to be a part of a complete treatment plan. Instead, the options provided to patients today are more hazardous, less effective, and more costly than those offered by these newer approaches of treating illness. Silver nanoparticles might be utilized to combat drug resistance using nanotechnology. Ayurveda and homoeopathy in India have long recognized the antibacterial effects of silver. The surface area to volume ratio may be improved by modifying the chemical and physical characteristics at the nanoscale." Bacteria of both types may be killed by using silver nanoparticles having a diameter between 10 and 100 nanometers (nm). It's possible that the usage of silver nanoparticles like these might help combat germs that are resistant to many antibiotics, such Pseudomonas aerogenitis.

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