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A Review of Silver Nanoparticles and Their Anti-Microbial Activity in Medicine

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Abstract

Silver Nanoparticles (AgNPs) has emerged as promising antimicrobial agents in modern medicine. This review shows the synthesis, antimicrobial mechanisms and medical applications of silver nanoparticles. It unique physicochemical property of medicinal applications is wound healing and burn treatment, treatment in multi drug resistant infection.

Key Words: Silver nanoparticles – nanotechnology – synthesis of silver particles – wounding healing – anticancer – medical application

1. INTRODUCTION:

Silver has been utilized for its antimicrobial properties for centuries. Silver nanoparticles have emerged as promising candidates in the fight against bacteria, fungi and certain viruses.

Silver is a precious metal that has been valued for centuries due to its unique properties and aesthetic appearance.

SYMBOL: Ag^+

LATIN WORD: argentum

ATOMIC NUMBER: 47

DENSITY: 10.49 g/cm^2

APPEARANCE: soft, white, lustrous, transition metal

COUNDUCTIVITY: high electric and thermal conductivity

MALLEABILITY AND DUCTILITY: high

REACTIVITY: exposed to air and moisture-form black layer

NANOPARTICLES:

Particles with a diameter between 1amd 100 nanometers than have unique properties due to their small size are known as nano particles, examples: gold nanoparticles, silver nanoparticles, zinc oxide nanoparticles, dendrimers and fullerenes, etc..,

Nanoparticles are used as follow:

Drug delivery – liposomes for cancer, etc..,

Medical imaging – iron oxide nanoparticles, etc..,

Tissue engineering – scaffolds for bone and cartilage repair, etc..,

Biosensing cancer treatment – hyperthermia/ photoablation .etc..,

NANOTECHNOLOGY:

Nanotechnology is the study and manipulation of matter at the nanoscale between 1to 100 nanometers to create materials with unique properties for diverse applications. In medicine field various applications like:

- Targeted drug delivery
- Diagnostics
- Electronics for faster and smaller components
- Environmental study for pollution control, etc..,

2. HISTORY:

Silver has been used in medicine for **thousands of years** due to its natural antimicrobial properties. In ancient civilizations used mostly for water purification and wound care , modern application – wound dressing and medical device coating , etc..,

Ancient history:

Circa 4000 BCE: Used for preserve food and water

19th century:

1852 – **Dr. J. Marison sims** – a pioneer in gynecology, used fine silver wire to repair vesicovaginal fistulas.
1880s – Karl Crede – German obstetrician – dilute silver nitrate and used it in the eye of new born which prevent ophthalmic neonatorum.

20th century:

1960s – Mayer et. al – used 0.5% silver nitrate solution as topical treatment for burn patients.
AYURVEDA – silver named as RAJATA
SIDDHA – these are formulated as BHASMA

Modern era;

- Medical devices – silver coatings – endotracheal tubes , urinary catheters ,
- Wound care – wound dressing , example: hydro fibers , foams ,
- Other uses – dental amalgams , bone prostheses , reduce dental caries ,

NANOTECHNOLOGY:

The term Nanotechnology was coined by Norio TониguchI in 1974.
1981 – Invention of STM scanning tunneling microscope – by Gerd Binning and Heinrich Rohrer – noble prize in physic in 1986.
1985 – Discovery of fullerenes (C60 bucky balls) – Harold Kroto, Richard Smalley, Robert Curl. – Noble price in chemistry in 1996 for carbon nanostructure.

Milestone	Year	Event	Impact
Feynman's Lecture	1959	Richard Feynman	Conceptual birth
Term coined	1974	Norio Taniguchi	Naming the field
STM invented	1981	Binning and Rohrer	Atomic manipulation
Fullerenes	1985	Kroto, Smalley, Curl	First nanomaterial
Carbon nanotubes	1991	Sumio Iijima	Versatile nanostructur es
NNI Launched	2000	U.S. Government	Massive funding surge

The advantages of nanotechnology has revolutionized medical application of silver nanoparticles (AgNPs) with enhanced medical properties and novel therapeutic capability of antimicrobial therapy.

3. FACTORS AFFECTING NANOPARTICLES:

- **SIZE :** smaller particle -higher activity (1-10), ultra-small AgNPs (<2nm) shows toxicity
- **Shape:** spherical common, anisotropic shapes (rods, triangles, plates) which enhances high energy facing activity.
- **Surface charge :** positive charge (+ve) interact with negative charge (-ve)
- **Ph:** changes in the ph shows the increase or decrease in ion exchanges.
- **Environmental condition:** temperature, pressure, barriers, etc., which alter the activity.

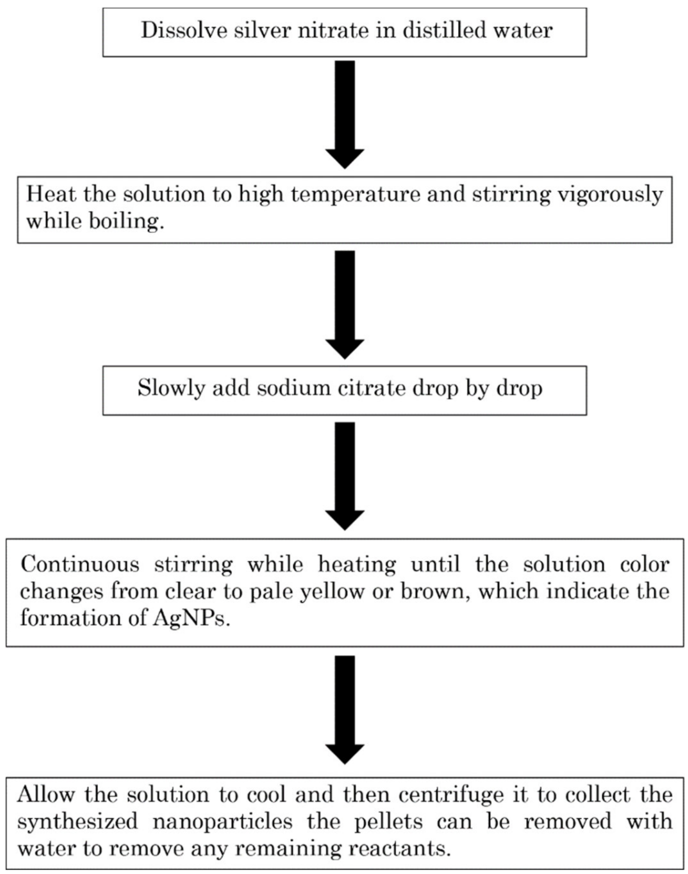
4. SYNTHESIS OF SILVER NANOPARTICLES:

CHEMICAL SYNTHESIS:

In this method involved reducing of silver salts (silver nitrate, $AgNO_3$) using chemical reducing agents.

Reducing agent: sodium borohydride ($NaBH_4$), sodium citrate, ascorbic acid, polyols – ethyl glycol, etc.
Stabilizing agents: PVP, PEG, Thiols, etc.
Advantages: capable for industrial production
Limitation: usage of toxic chemicals may affect biocompatibility, unwanted chemical interaction with biological system.

Synthesis:



PHYSICAL SYNTHESIS METHOD:

This process carry through energy intensive that do not required chemical reducing agents result in pure nanoparticles.

Methods:

- Laser ablation
- Evaporation - condensation
- Gamma irradiation
- Arc discharge

Advantage: high purity nanoparticles, no chemical contamination.
Limitation: high energy consumption lower production yield, equipment used are expensive

GREEN SYNTHESIS (BIOLOGICAL METHODS):

In this method, biological materials such as plant extract, microorganisms, and biomolecules are used, and reducing and stabilizing agents also used.

Biological source:

- Plant extract – Azadirachta indica, Alovera, curcuma longa (turmeric)
- Microorganisms – bacteria (bacillus, pseudomonas), fungi (aspergillus, fusarium)
- Biomolecules – proteins, polysaccharides, and amino acids.

ADVANTAGES:

- Environmental friendly
- Cost efficiency
- Readily available
- Reduced toxicity
- Also the product is biocompatible nanoparticles.

LIMITATION:

- Batch to batch variation
- Longer synthesis time in some cases
- Contamination threatens
- Complex mixture make difficult mechanism.

5. ANTI-MICROBIAL MECHANISMS OF SILVER NANOPARTICLES

"MULTIMODAL ACTION"

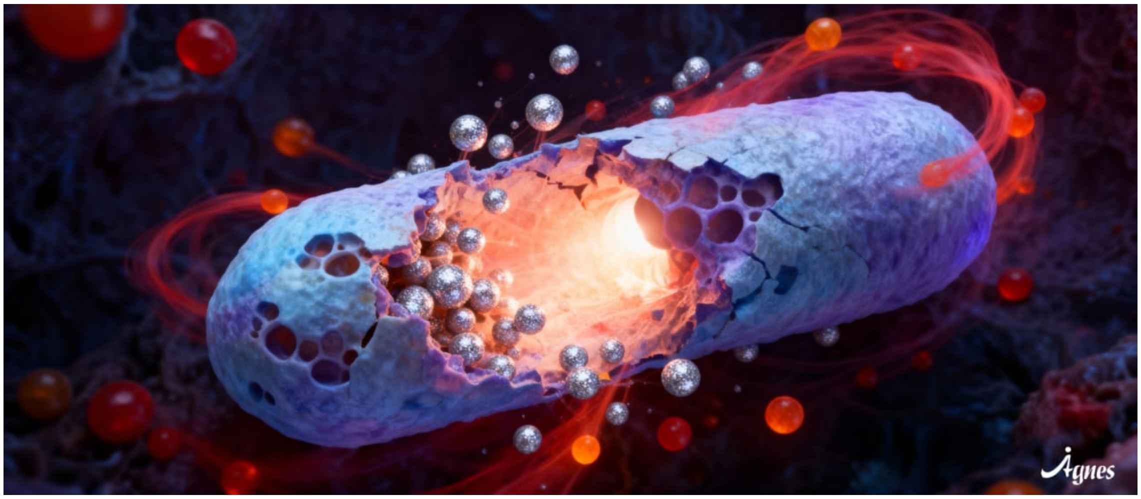
CELLULAR MEMBRANE DISTRUPTION:

AgNPs released silver ions which interact with cell wall and causing structural damage and functional distraction to the bacteria

REACTIVITY OXYGEN SPECIES (ROS) GENERATION:

AgNPs are potent inducers, they depletes cellular antioxidant defenses and amplifies oxidative stress, interact with electron transport chain electron leaking & superoxide formation.

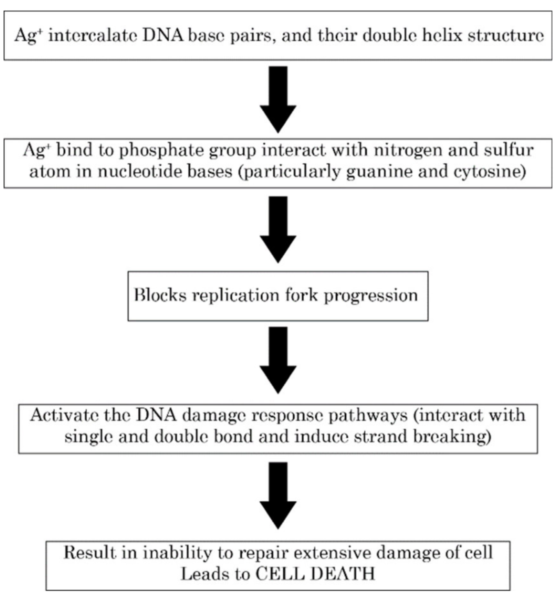
AgNPs are potent in intracellular reactive oxygen species, which plays a major role in anti-microbial action.



SILVER- DNA INTERACTION:

Silver ions and nanoparticles interact directly with DNA, causes structural and functional damage. Silver – induced DNA damage interferes with the replication process.

MECHANISM:



EFFECT ON BACTERIA:

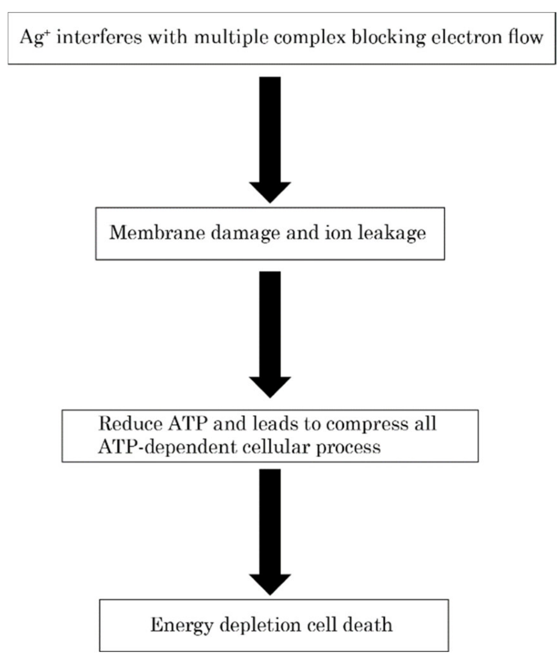
The cell wall structure of gram – positive, gram – negative bacteria influences AgNPs interactions.

GRAM -NEGATIVE BACTERIA: Consists of thin peptidoglycan layer, periplasmic space and pores

GRAM – POSITIVE BACTERIA: thick peptidoglycan layer, AgNP slow penetrate but less protection once break

Hence, it shows variable patterns of penetration attacks, this report shows greater sensitivity in gram-negative bacteria due to its thin peptidoglycan layer.

Inter-fear with bacterial respiration:



NOTES:

Nanoparticle – specific effects:

- Direct physical damage to membrane.
- Enhances cellular uptake through endocytosis.

Silver ion effect:

- Rapid diffusion and penetration.
- Strong binding to biomolecules.
- DNA interaction and damage.

WOUNDING HEALING AND BURN TREATMENT:

It include infection prevention, inflammation modulation and tissue regeneration.

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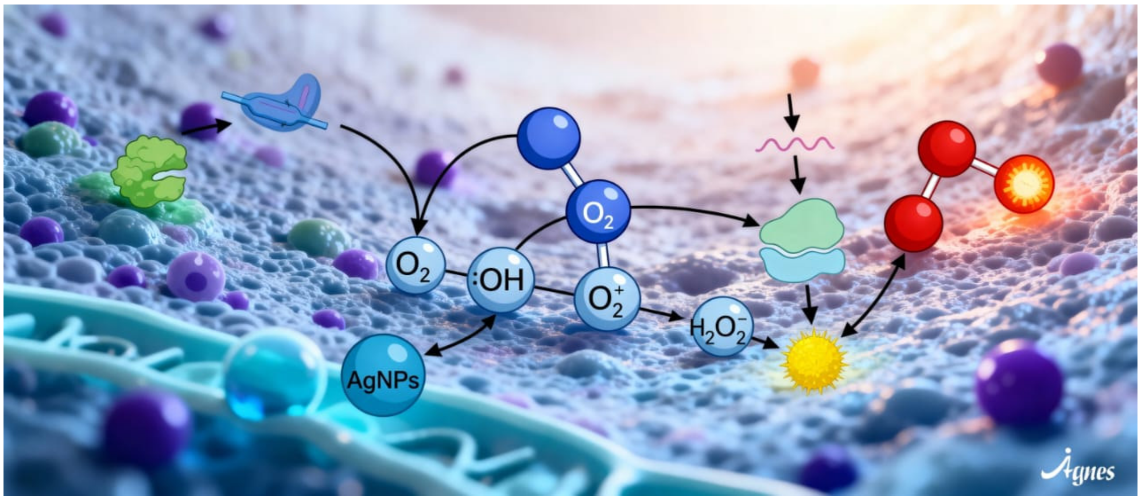
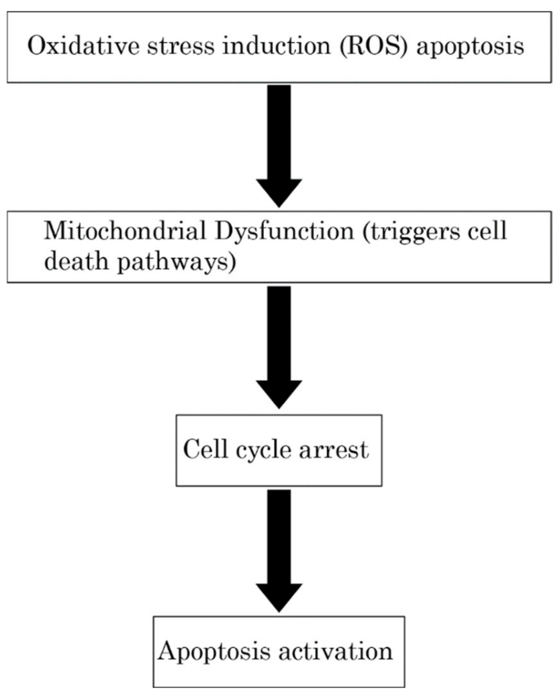


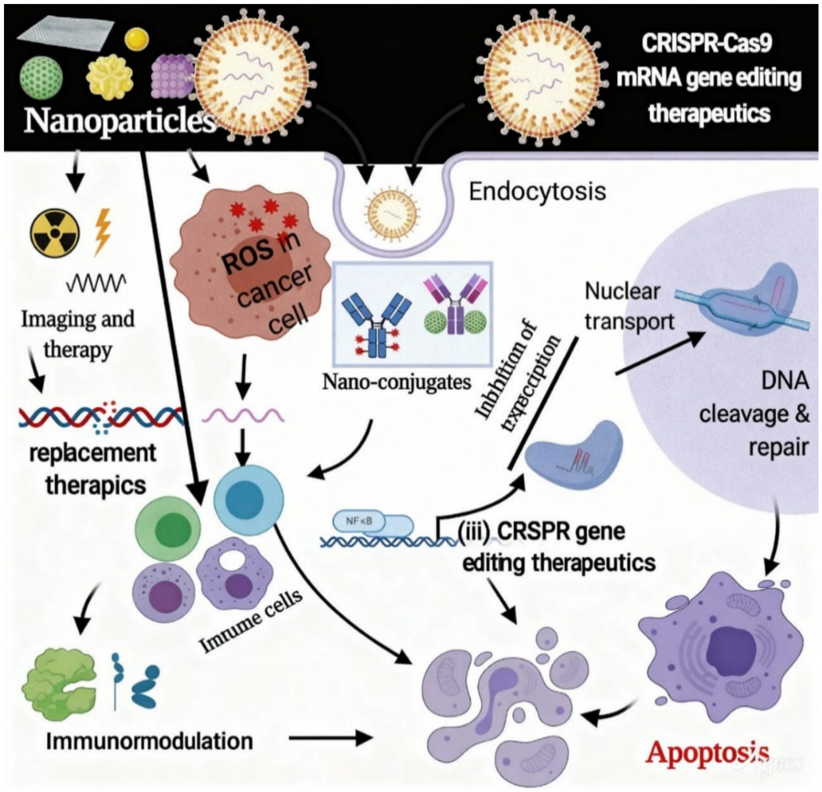
ANTI-CANCER ACTIVITY:

It is an explored carrier

- Doxorubicin – loaded AgNPs – Enhanced tumor cell killing with reduced systemic toxicity.
- Paclitaxel delivery: Improved solubility and targeted delivery.

MECHANISMS:





MEDICAL APPLICATION:

- Wounding healing and burning treatment :
  - Forms – hydrogels, wound dressing, gel and creams, sprays.
- Medical device and implant coating :
  - Device: Orthopedic implants, cardiovascular device, urinary catheters, dental implants.
- Coating – control release from coating, plasma treatment.
- Balancing antimicrobial activity and biocompatibility.
- Dental: dental cones, root canal sealers, caries prevention.
- Drug delivery system : antibiotic delivery , controlled release (eg: AgNPs + ampicillin / vancomycin - - active against MRSP
- Anticancer drug delivery: active against both gram positive and negative bacteria.

CONCLUSION:

Silver nanoparticles stand at both ancient wisdom and modern innovation. Antimicrobial property of silver's has been recognized and nanotechnology has unlocked therapeutic potential, recent research of silver dominate in multiple applications like wound management, device coating, treatment of resistance infections.

The journey of silver from ancient to modern Nano medicine, explain that traditional knowledge combined with modern science, as research progress, clinical trials, also act against infective diseases and antimicrobial resistance.

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