ISSN NO: 2770-2936
January, 2026

# A Brief Review Of Articles Published On The Results Of Certain Scientific Studies Dedicated To The Application Of Silver Nanoparticles In Medicine And Pharmacy.

**Atamuradov Sh.I., Umirzaqov B.E**
The Military Medical Institute of the University of Military Security and Defense of the Republic of Uzbekistan

**Abstract.** In recent years, nanotechnology has become one of the key driving forces in the advancement of modern medicine, leading to increased interest in the study of silver nanoparticles and the expansion of their practical applications. Owing to their pronounced antibacterial and antiseptic properties, silver nanoparticles are increasingly used in medical and pharmaceutical practice. This article presents a brief analytical review of scientific studies published in recent years in the global scientific literature, focusing on the application of silver nanoparticles in medicine and pharmacy.

**Keywords:** silver nanoparticles, nanotechnology in medicine, antibacterial activity, antiseptic properties, medical application.

**Introduction.** In recent decades, the rapid development of nanotechnologies has opened up wide opportunities for creating new scientific directions and innovative diagnostic and treatment methods in the fields of medicine and pharmaceuticals. The unique physical, chemical and biological properties of materials at the nanoscale enable their effective application in disease diagnosis, treatment, and prevention. From this point of view, in recent years, scientific interest in silver nanoparticles has significantly increased. Silver nanoparticles are characterized by a high specific surface area and the ability to interact actively with microorganisms. As a result of these properties, they exhibit strong antibacterial, antiviral, and antiseptic effects. This is especially important considering the increasing number of microorganisms resistant to antibiotics, which underlines the relevance of using silver nanoparticles as an alternative or additional therapeutic agent. In medical practice, silver nanoparticles are widely used in wound dressings, antiseptic agents, components of implantable medical materials, as well as in targeted drug delivery systems. In the field of pharmacy, they are considered as promising components for increasing the effectiveness and safety of drugs. However, issues related to the biocompatibility, potential toxic effects, and mechanisms of action of silver nanoparticles are still not fully understood, indicating the need for further in-depth scientific research in this area.

**Research objective.** Taking the above-mentioned into account, the main objective of this work is to highlight the prospects for the use of silver nanoparticles in medicine and pharmaceuticals by analyzing and summarizing the results of studies published in the world's scientific literature in recent years.

**Materials and Methods.** This work is mainly of a review and analytical nature and includes a systematic analysis of published scientific literature on the use of silver nanoparticles in medicine and pharmacy. The analysis was carried out in January 2026, using international peer-reviewed articles, reviews, and clinical studies published over the past 10–15 years in the databases Scopus, Web of Science, PubMed, Google Scholar, CrossRef, and "Free Article PMC". The search was conducted using the following terms: "silver nanoparticles," "nanotechnology in medicine," "antibacterial, antiseptic, medical effect." The results of the search provided a list of scientific reports, article reviews, and literature relevant to the topic, available within the last 10 years from the date of the search. In research areas where no new information was found, the search depth was extended by an additional 5 years.

The following criteria were considered when selecting literature: the relevance and actuality of the research, the presence of experimental or clinical significance in the results, the physical-chemical properties of silver nanoparticles (size, shape, high surface area, and modified surfaces), as well as data concerning their biological activity and safety. The data obtained during the analysis were compared, evaluated, summarized, and systematized, which allowed for the identification of the medical and pharmaceutical application directions and prospective opportunities of silver nanoparticles. In addition, differences in results and general trends highlighted in various studies were also reviewed, creating a basis for future research in this field.

**Results and Discussion.** A group of scientists—Rai M., Yadav A., Gade A. (2009)—in their research, noted that silver has historically been used as an antiseptic and antibacterial agent, and that metallic silver, silver nitrate, and silver sulfadiazine have been used in the treatment of wounds, burns, and infections. However, with the advent of antibiotics, the use of silver became less common.

According to the authors, from a scientific and technical point of view, the ability of nanotechnology to reduce metals to the nanoscale ($10^{-9}$ m) significantly changes their physical, chemical, and optical properties, and these changes once again turn silver into a powerful antimicrobial agent.

The researchers presented the following main results and conclusions in their article:

- Antimicrobial effect of silver nanoparticles. The article emphasizes that silver nanoparticles (AgNPs) possess strong antibacterial activity, especially against both Gram-negative and Gram-positive bacteria. This effect can also be utilized against antibiotic-resistant strains;
- Nanotechnology enhances the effectiveness of silver. Reduction of silver to the nanoscale increases its surface area and chemical reactivity, thereby enhancing its interaction with skin and microorganisms. This is significantly different from standard silver molecules, as nanoparticles interact with microorganisms more rapidly and efficiently;
- Medical applications of silver nanoparticles. The study notes that AgNPs can be widely used in the following fields: production of silver-based wound dressings, development of antibacterial creams and lotions, creation of medical devices coated with silver, as well as in the production of nanogels and nanolotions. These findings highlight the broad potential of AgNPs in clinical practice;
- Potential against antibiotic-resistant microorganisms. The authors point out that many pathogenic bacteria have become resistant to antibiotics. Therefore, AgNPs are of great importance as a novel antimicrobial agent.

The authors also highlighted the social and scientific significance of silver nanoparticles in their article. In particular, they noted that silver nanoparticles, when combined with traditional antibiotics, may enhance their effectiveness, making AgNPs a promising agent against new or antibiotic-resistant infections, and that they are widely used as nanobiomaterials in various fields of modern medicine.

Rai M. and his colleagues described silver nanoparticles as a "new generation antimicrobial agent," providing extensive and scientifically grounded information about their high antimicrobial activity, potential against antibiotic-resistant bacterial infections, and medical applications. The researchers Franci G, Falanga A, Galdiero S, and co-authors (2015) published an article in the journal Molecules on "The Antibacterial Effect of Silver Nanoparticles (AgNPs) and Their Prospective Use as Antibacterial Agents in Treating Infections." The main aim of their research was to publicize the potential of silver nanoparticles in combating infections and to highlight their antibacterial activity, particularly emphasizing the need to develop new strategies against a variety of antibiotic-resistant bacteria. The authors point out that antibiotic-resistant (multidrug-resistant, MDR) bacteria pose a major challenge in the fight against infections. For this reason, silver nanoparticles are attracting great interest as new antimicrobial agents. Silver has long been known for its strong antibacterial effects, and nanotechnology has made silver an even more effective antimicrobial substance.

In addition, the authors propose several mechanisms for the activity of silver nanoparticles. These mechanisms include: disruption of the cell membrane – AgNPs disrupt the cytoplasmic membrane of bacteria, negatively affecting their internal functions; interaction with nucleic acids – AgNPs may interact with bacterial DNA and RNA, which inhibits their replication process; inhibition of biofilms – AgNPs destroy the structure of biofilms formed by bacteria, thereby increasing effectiveness against antibiotic-resistant infections. This means that the activity of AgNPs is formed by a combination of various mechanical actions. Franci and colleagues noted that AgNPs significantly reduce the growth of biofilms produced by bacteria resistant to beta-lactam antibiotics. In particular, when bacterial biofilm structures are treated with AgNPs, most of the microflora is destroyed. As a result of this property to disrupt biofilms, new opportunities open up in the treatment of infections.

The authors emphasize that the antibacterial activity of AgNPs depends on their physical and chemical properties, such as particle size and shape, surface area, and synthesis method. These factors determine the strength of the effect of AgNPs on microorganisms. According to researchers, AgNPs become a targeted and

ISSN NO: 2770-2936
January, 2026

broad-spectrum antimicrobial agent. Their effects on Gram-positive and Gram-negative bacteria, their impact on biofilms, and their effectiveness against strains resistant to multiple antibacterial drugs justify their inclusion in the group of broad-spectrum antimicrobial agents. Scientists note that AgNPs have the property of creating synergy with antibiotics. When combined with antibiotics, they enhance each other's effects, especially when combined with antibiotics such as ampicillin and vancomycin. This combined effect allows the reduction of antibiotic doses and increases their effectiveness.

As the authors point out, although AgNPs have high antibacterial efficacy, their toxicity and effects on the environment should also be considered. This demonstrates the need for further research on their biological compatibility, toxicity, and mechanism of action. In conclusion, Franci and colleagues (2015) state that silver nanoparticles have great potential as antibacterial agents. A thorough study of them provides information on their broad-spectrum antibacterial effect, efficiency against biofilms, synergistic possibilities with antibiotics, and their use in new therapeutic strategies.

Another group of scientists, Durán N., Marcato P.D., De Souza G.I., and others (2007), focused their research on the environmentally friendly biosynthesis method of producing silver nanoparticles, that is, synthesizing them using the fungal (mushroom) method derived from harmful microorganisms, and analyzing their antibacterial activity. The authors propose biological (biosynthesis) methods that are less toxic, environmentally sustainable, and more convenient to use, as opposed to traditional chemical or physical methods. Silver nanoparticles synthesized using this method provide increased effectiveness against infections.

In the article, the authors describe the synthesis of silver nanoparticles from silver ions through fungal organisms such as Quarzarium microsporum. Fungal cells reduce $Ag^+$ ions to $Ag^\circ$ (metallic silver) in a biological way. According to the authors, this method has several advantages, including high efficiency, environmental safety, the ability to obtain particles with a large surface area, and reduced contamination related to chemical substances. The study's results showed that biosynthesized silver nanoparticles demonstrated significant antibacterial activity against various Gram-negative and Gram-positive bacteria. This effect is mainly expressed through the disruption of bacterial cell membranes by silver particles, inhibition of enzymatic processes, and negative impact on the metabolic functions of microorganisms.

The authors identified the following as the main antibacterial mechanisms: disruption of the cell membrane – AgNPs disrupt bacterial membranes, damaging their internal functions; release of metal ions – silver nanoparticles release $Ag^+$ ions, which disrupt cell activity; oxidative stress – the excitation of silver increases the number of reactive oxygen species, which has a harmful effect on bacteria. The article emphasizes that biosynthesized AgNPs can be used in medicine, as antibacterial coatings for wounds, and in conjunction with pharmaceutical products. These findings suggest new strategic directions in combating the spread of antibiotic-resistant microorganisms.

This study conducted by the authors is considered highly important. The results propose an environmentally clean synthesis method, describe the antibacterial action mechanisms of silver nanoparticles, and serve as a basis for creating safer and more effective antimicrobial agents. Another group of scientists (Lara H.H. and colleagues) also studied the antibacterial properties of silver nanoparticles and published their findings in an article.

The article broadly covers the antibacterial and virucidal effects, mechanisms, and biological application prospects of silver nanoparticles (AgNPs). It also analyzes how AgNPs can assist in the prevention of infectious diseases and their use in antibacterial and antiviral therapies.

Based on the results of the study, it is emphasized that silver has been used as an antiseptic and antibacterial agent for many centuries. For example, it has been used in wound healing, as a surface coating for catheters and medical instruments, and in water disinfection filters. The development of nanotechnology has enabled the enhancement of the antibacterial and antiviral activity of silver by reducing it to the nanoscale.

According to the article, the broad-spectrum effect of AgNPs (silver nanoparticles) against bacteria occurs through several mechanisms. For instance, direct interaction with the cell membrane allows AgNPs to bind to the bacterial cell wall, disrupting the membrane structure. In addition, AgNPs interact with enzyme and protein functions via S–S (disulfide) bonds, disrupting the structure and function of proteins. Furthermore, the internal functioning of the cell is impaired, leading to a loss of bacterial metabolic activity, which eventually results

ISSN NO: 2770-2936
January, 2026

in bacterial death. AgNPs are also highly effective against antibiotic-resistant bacteria. For example, their effects have been demonstrated against strains such as MRSA, Pseudomonas aeruginosa, and ampicillin-resistant E. coli.

The authors note that AgNPs may also interact with viruses. In particular, they directly bind to viruses with a lipid envelope and prevent their entry into host cells. In the case of the HIV1 virus, it has been shown that AgNPs bind to the gp120 protein, preventing the virus from attaching to the CD4 receptor. This mechanism stops the development of HIV infection step by step. Moreover, AgNPs may also have virucidal activity against other viruses (such as influenza virus and hepatitis B), although this area still requires further research.

The authors emphasize that AgNPs have a high potential for clinical application, but that studies on their complete biocompatibility and long-term safety are still insufficient. Therefore, further research is required before clinical use. The study conducted by Lara H.H. and colleagues (2011) presents scientifically based information about the broad-spectrum antibacterial effects of silver nanoparticles, their virucidal (antiviral) properties, efficacy against biofilms and antibiotic-resistant bacteria, as well as prospects for clinical application. Researchers Chen X. and Schluesener H.J. (2008) presented a scientific article dedicated to silver nanoparticles (nanosilver/AgNPs). In their work, they analyzed the medical use of nanoscale silver, its physical and biological properties, and potential toxicological issues requiring further investigation.

The authors note that although silver nanoparticles (nanosilver) are non-sterile, they possess strong antibacterial properties at the nanoscale (<100 nm) and have several physical, chemical, and biological characteristics. These properties differ significantly from those of traditional silver and expand its potential for medical applications. The article discusses the nanoparticles' high indices of biological activity, especially antibacterial effects, the nanoscale-related changes in physical and chemical properties, and their enhanced ability to penetrate biological systems.

According to the analysis by Chen and Schluesener, silver nanoparticles are considered promising for widespread use in various fields, such as antibacterial coatings for different types of tissues (for example, clothing, paints, bandages), coating the surfaces of implants and prosthetics with silver, applications in wound and burn treatment, as disinfectants, water purification and antimicrobial agents, in some cases as contraceptive agents, and in a wide range of disinfectant products (such as room sprays and other sanitary products).

These findings indicate that silver nanoparticles may play an important practical role in the fields of medicine and hygiene.

The authors emphasize that although AgNPs possess a broad spectrum of biological activity and effectiveness, their interactions with the human body, biocompatibility, long-term toxic effects, and structure are still not fully understood.

They report that AgNPs can enter the body through various routes (skin, respiratory tract). However, there is insufficient information about the accumulation of silver nanoparticles in organs, their distribution mechanisms, breakdown, and metabolism. Therefore, additional research is required to assess their safety and to identify potential toxic effects.

While the authors acknowledge the benefits of working with silver nanoparticles, they also consider it necessary to examine the effects of these products on the body and their potential environmental risks. They stress that the rapid development of nanotechnology may also sustain risks for humans and living organisms.

Chen and Schluesener (2008) described silver nanoparticles as a promising "nanoproduct" for medical use, pointing out their high antibacterial effectiveness and emphasizing opportunities for application in various fields of medicine (from wound healing to implant hygiene). However, they specifically noted that toxicological studies must be conducted.

Chernousova S. and Epple M. (2013) provided a broad scientific review of the therapeutic efficiency and antibacterial effects of silver (Ag) in their article. They analyzed the effects of metallic silver, silver ions ($Ag^+$), and silver nanoparticles on bacteria, cells, and higher organisms, including their antibacterial mechanisms and safety aspects.

The authors note that silver has long been used as an antiseptic and antibacterial agent. However, in recent years, its nano form—silver nanoparticles (AgNPs)—have become an extensive research subject, as they further enhance antibacterial effectiveness.

The article classifies various forms of silver, including metallic silver (in liquid and solid states), silver ions (Ag+), and silver nanoparticles (AgNPs), and analyzes the mechanisms by which each affects microorganisms.

The antibacterial activity mechanisms of silver are explained as follows: interactions of Ag+ ions with microorganism membranes; direct contact of silver nanoparticles (AgNPs), which disrupt the cytoplasmic membrane of bacteria; the generation of reactive oxygen species (ROS) by AgNPs, which disrupts bacterial metabolism; and the biochemical effects of ions—interaction with enzymes and proteins, as well as toxic effects on the organism.

The authors note that the broad-spectrum antibacterial action is the most important characteristic of AgNPs: they affect both gram-negative and gram-positive bacteria, and are also effective against antibiotic-resistant strains.

The entry of Ag+ ions into microbial cells and their subsequent disruption plays an important role in combating infections. According to the authors, the therapeutic window of silver—that is, the range of safe and effective concentration—may be narrower than usual. This indicates the importance of regulatory analysis and monitoring when using silver products in the human body. However, as they point out, if used correctly, the risk to humans and the environment may be relatively limited. The article notes that the effects of silver are not limited to only antimicrobial action. It also has additional biological effects, influencing various cells and organ systems through its ions and particle forms. Therefore, a comprehensive analysis of its biocompatibility and toxic effects is required.

The article by Chernousova and Epple (2013) is considered a fundamental review of the significance of silver as an antibacterial agent. It broadly covers, on a scientific basis, the differences between the metal, ionic, and nanoparticle forms of silver, the mechanisms of antibacterial action, aspects of effectiveness and safety, and prospects for clinical and industrial application. Chernousova and Epple's (2013) research describes the antibacterial effects of silver and reliably confirms, based on scientific works, the distinctions between its metal, ionic, and nano forms. They also analyze the necessity of effective but careful use of silver, its safety range, and therapeutic compositions.

In his article, Klasen H.J. (2000) provides a scientific review from a historical perspective, unlike the rapidly spreading modern nanotechnological forms of silver. That is, it gives information about the centuries-long medical use of silver and its ongoing historical role even during the development of antibiotics. According to the historical review by Klasen H.J., the antibacterial effect of silver has been known in traditional medicine for centuries. In the 19th and 20th centuries, compounds such as silver nitrate and silver sulfadiazine were used as effective antibacterial agents in burns and various wounds. Even today, preparations containing silver are widely used, but there are some problems related to their effectiveness against gram-negative bacteria.

Singh A., Jain D., Upadhyay M.K., et al. (2010), in their article, highlight scientific studies about the "green" (environmentally friendly) synthesis of silver nanoparticles (AgNPs) using plant extracts. The main goal of the research was to determine and validate a convenient, safe, and inexpensive method for the biological (ecological) synthesis of AgNPs, different from chemical or physical methods. Singh A., Jain D., Upadhyay M.K., and colleagues scientifically demonstrated that silver nanoparticles can be synthesized in an eco-friendly way using plant extracts and proved the antibacterial activity of these AgNPs. This method opens up opportunities for the safer and more effective use of silver nanotechnologies in the fields of medicine and pharmacy. In the article published by Johnston H.J., Hutchison G., Christensen F.M., Peters S., Hankin S., Stone V. (2010), they systematically analyzed existing scientific data on the toxic effects of silver and gold nanoparticles, which are widely used in various products such as vaccines, clothing, and wound dressings. As a result, the article scientifically reviewed how AgNPs affect the human and animal body, which organs they may distribute to, and the mechanisms underlying these effects. According to the analysis conducted by Johnston and colleagues, there is a significant amount of data about the toxic effects associated with AgNPs and AuNPs, but further research is needed for a complete understanding. Toxic effects may manifest through inflammatory, oxidative stress, and genotoxic mechanisms. The degree of toxicity depends on particle size, concentration, and long-term exposure. Currently, there are only a limited number of in vivo and in vitro studies available, and there is a need for coordination between these studies.

ISSN NO: 2770-2936
January, 2026

This article is one of the fundamental works in the field of nanotechnology toxicology and is considered one of the first comprehensive reviews on the safety and biocompatibility assessment of silver nanoparticles.
Monteiro D.R. and colleagues (2009) conducted a study focused on the role of silver and silver-based nanotechnologies in reducing the effects of microorganisms on medical devices. The authors analyzed how these compositions can beneficially affect bacterial adhesion and biofilm formation.
The study by Monteiro and colleagues demonstrated that materials treated with silver and AgNPs reduce microbial adhesion on medical devices, thereby lowering the risk of infection. AgNPs play an important role in preventing biofilm formation, opening up new prospects for combating antibiotic-resistant infections. The release of $Ag+$ ions and the structure of silver provide its antibacterial effect.
Eckhardt S. and colleagues (2013) provided a comprehensive scientific review about the interactions of silver nanoparticles (AgNPs) with biological organisms, especially peptides, proteins, bacteria, and their potential medical applications.
The article by Eckhardt et al. scientifically substantiates the molecular interactions of AgNPs with peptides and bacteria, their antibacterial mechanisms, and the prospects for their medical application, thus providing fundamental knowledge to make AgNPs an effective tool in modern nanomedicine.
The article by Atiyeh B.S. and colleagues (2007) is a literature review that analyzes the effect of silver on infection control in burn wounds and the wound-healing process. The aim of the review is to determine the balance between the antibacterial activity and toxic effects of silver and to compile a review of studies assessing their clinical value.
Their literature review showed that silver has great potential in controlling burn and wound infections, but there are issues regarding toxicity to the wound and to cells.
In the study conducted by Greulich C. and colleagues (2012), the authors investigated the toxic effects of silver ions ($Ag+$) and PVP-stabilized silver nanoparticles (70 nm) in terms of their harm to bacteria and human cells.
This article shows that silver nanoparticles damage human liver cells, and the main cause of this damage is an increase in reactive oxygen species inside the cell as a result of oxidative stress. The effect of silver ions ($Ag^+$) does not play a primary role in this process, and the toxic effect can be reduced with the help of antioxidants.
In the scientific article published by Kim, S., Choi J. E., Choi J. (2009) and others, the researchers investigated the mechanism of damage caused by silver nanoparticles to human liver cancer cells. The objective was to answer whether silver nanoparticles are directly toxic to the cell or whether the damage is caused via oxidative stress.
The article shows that silver nanoparticles damage human liver cells, and the main cause of this damage is an increase in reactive oxygen species inside the cell due to oxidative stress.
The effect of silver ions ($Ag^+$) does not play a primary role in this process; the nanoparticles themselves have intrinsic toxicity. The toxic effect can be reduced with the help of antioxidants.The scientific article by Le Ouay B., Stellacci F. (2015) is a review about the physicochemical processes underlying the antibacterial effects of silver nanoparticles. The authors broadly cover which mechanisms are at play in the antibacterial efficacy of AgNPs, what factors influence them, and the importance of chemistry in this process.
The study by Le Ouay and Stellacci (2015) shows that the antibacterial effect of silver nanoparticles is mainly realized through oxidative dissolution (release of $Ag+$), and in this process, surface chemistry, ion release, interaction with membranes, and the effect of anions play significant roles. AgNPs systems serve as a promising approach for modern therapies and materials against antibiotic-resistant microorganisms. The authors Rizzello L. and Pompa P.P. (2014) conducted a review aimed at systematically analyzing the scientific data on the use of AgNPs as medical antimicrobial agents and the effectiveness of AgNPs in specific devices (catheters, implants, drug carriers), as well as outlining future directions.
This article is a contemporary review on antimicrobial agents based on silver nanoparticles (AgNPs) and on medical devices treated with them. The review analyzes the synthesis methods of AgNPs, their antibacterial effects, devices treated with AgNPs, and their clinical prospects. Their study showed that antibacterial drug agents and medical devices made from silver nanoparticles can effectively help prevent the spread of infections and bacteria adhesion. However, issues of safety, biocompatibility, and optimal dosing play a crucial role in implementing this technology in clinical practice.

The authors Hadrup N. and Lam H.R. (2014) published a review article analyzing the toxic effects of silver when administered orally. The paper provides scientifically grounded information about the distribution in the body, toxic effects, and risks associated with silver ions (Ag+), silver nanoparticles (AgNPs), and colloidal silver. The review published by these researchers indicates that oral administration of silver ions, silver nanoparticles, and colloidal silver can have toxic effects; they are distributed throughout the body and may cause adverse effects in a dose-dependent manner. The toxic effect of AgNPs is largely described as being associated with the Ag+ ions released from the particles. This article serves as an important resource for assessing the health effects and safety of AgNPs, as it broadly covers the effects of oral administration, distribution in organs, and dose–response relationships.

The article authored by Tang S. and Zheng J. (2018) is a comprehensive review that covers the antibacterial activity of silver nanoparticles and the effects of their structure (such as size, shape, and surface chemistry). In order to better understand the efficacy of AgNPs in combating infections, the authors place significant emphasis on structure–activity relationships. The article highlights that various antibiotic-resistant bacteria pose a serious challenge in controlling infections, and silver nanoparticles offer great promise as a new solution to this problem. According to the researchers, due to their broad-spectrum antibacterial properties, AgNPs could serve as important components for future nanodosages, drug delivery systems, and medical materials.

Tang and Zheng's study scientifically demonstrates that structural factors (size, shape, surface chemistry) play a vital role in the antibacterial activity of silver nanoparticles. Moreover, they propose strategies for optimizing the structure of AgNPs in order to enhance their effectiveness against bacteria, thus laying the groundwork for the development of new nanoproducts in the fight against infections.

**Conclusion**. The results of numerous scientific studies in recent years show that silver nanoparticles belong to the category of nanomaterials that have great scientific and practical significance in medicine and pharmacy. Their strong antibacterial, antiseptic, antiviral, and fungicidal activities provide a basis for considering silver nanoparticles as a promising tool in combatting antibiotic-resistant microorganisms. All reviewed sources emphasize that the biological activity of silver nanoparticles is mainly determined by their physicochemical properties, including size, shape, concentration, and surface structure. Nanoparticles with smaller sizes and larger surface areas can effectively interact with the membranes of microorganisms, disrupt membrane integrity, inhibit enzymatic systems, and enhance oxidative stress through the generation of reactive oxygen species. Collectively, these mechanisms disrupt the life processes of bacteria and other pathogenic microorganisms. At the same time, research results indicate that the effect of silver nanoparticles is not limited only to microorganisms; under certain conditions, they may also exert toxic effects on living tissues and human cells. The toxic effect is primarily associated with the release of Ag+ ions, the development of oxidative stress, mitochondrial dysfunction, and damage to the cell's genetic apparatus. Therefore, all sources point out the necessity of strictly controlling the dosage, duration, and methods of application when using silver nanoparticles for medical purposes. A general analysis of the literature reveals that, in order to widely introduce silver nanoparticles into medical practice, it is important to standardize their synthesis methods, improve biocompatibility, minimize toxic effects, and conduct comprehensive studies aimed at evaluating long-term effects. In particular, technologies such as "green synthesis," surface modification, and their application in composite materials present significant scientific interest due to their potential to improve the safety and efficacy of silver nanoparticles.

Overall, based on the results of the reviewed literature, silver nanoparticles are evaluated as innovative nanomaterials with high potential for modern medicine and pharmacy. Their rational and scientifically grounded use could help create effective tools against antibiotic-resistant infections and improve the safety of medical devices and pharmaceutical forms. At the same time, in-depth investigation of their potential risks and the development of safe application criteria remain among the main priorities for future research.

**References:**

1. Rai M., Yadav A., Gade A. Silver nanoparticles as a new generation of antimicrobials. *Biotechnology Advances*. 2009;27(1):76–83.
2. Franci G., Falanga A., Galdiero S., et al. Silver nanoparticles as potential antibacterial agents. *Molecules*. 2015;20(5):8856–8874.

3. Durán N., Marcato P.D., De Souza G.I., et al. Antibacterial effect of silver nanoparticles produced by fungal process. *Journal of Biomedical Nanotechnology*. 2007;3(2):203–208.
4. Lara H.H., Garza-Treviño E.N., Ixtepan-Turrent L., Singh D.K. Silver nanoparticles are broad-spectrum bactericidal and virucidal compounds. *Journal of Nanobiotechnology*. 2011;9:30.
5. Chen X., Schluesener H.J. Nanosilver: A nanoproduct in medical application. *Toxicology Letters*. 2008;176(1):1–12.
6. Chernousova S., Epple M. Silver as antibacterial agent: Ion, nanoparticle, and metal. *Angewandte Chemie International Edition*. 2013;52(6):1636–1653.
7. Zhang X.F., Liu Z.G., Shen W., Gurunathan S. Silver nanoparticles: synthesis, characterization, properties, applications, and therapeutic approaches. *International Journal of Molecular Sciences*. 2016;17(9):1534.
8. Klasen H.J. Historical review of the use of silver in the treatment of burns. *Burns*. 2000;26(2):117–130.
9. Singh A., Jain D., Upadhyay M.K., et al. Green synthesis of silver nanoparticles using plant extracts. *Digest Journal of Nanomaterials and Biostructures*. 2010;5(2):483–489.
10. Johnston H.J., Hutchison G., Christensen F.M., et al. A review of the in vivo and in vitro toxicity of silver and gold nanoparticles. *Critical Reviews in Toxicology*. 2010;40(4):328–346.
11. Monteiro D.R., Gorup L.F., Takamiya A.S., et al. Silver nanoparticles: influence of size on antimicrobial activity. *Nanomedicine*. 2009;4(5):527–538.
12. Eckhardt S., Brunetto P.S., Gagnon J., et al. Nanobio silver: Its interactions with peptides and bacteria. *Chemical Reviews*. 2013;113(7):4708–4754.
13. Atiyeh B.S., Costagliola M., Hayek S.N., Dibo S.A. Effect of silver on burn wound infection control and healing. *Burns*. 2007;33(2):139–148.
14. Greulich C., Braun D., Peetsch A., et al. The toxic effect of silver ions and silver nanoparticles towards bacteria and human cells. *Materials*. 2012;5(9):1557–1571.
15. Kim S., Choi J.E., Choi J., et al. Oxidative stress-dependent toxicity of silver nanoparticles in human hepatoma cells. *Toxicology in Vitro*. 2009;23(6):1076–1084.
16. Le Ouay B., Stellacci F. Antibacterial activity of silver nanoparticles: A surface science insight. *Nano Today*. 2015;10(3):339–354.
17. Rizzello L., Pompa P.P. Nanosilver-based antibacterial drugs and devices. *Current Opinion in Biotechnology*. 2014;30:94–102.
18. Hadrup N., Lam H.R. Oral toxicity of silver ions, silver nanoparticles and colloidal silver. *Basic & Clinical Pharmacology & Toxicology*. 2014;115(1):21–26.
19. Tang S., Zheng J. Antibacterial activity of silver nanoparticles: Structural effects. *Advanced Healthcare Materials*. 2018;7(13):1701503.
20. McShan D., Ray P.C., Yu H. Molecular toxicity mechanism of nanosilver. *Journal of Food and Drug Analysis*. 2014;22(1):116–127.
21. Morones J.R., Elechiguerra J.L., Camacho A., et al. The bactericidal effect of silver nanoparticles. *Nanotechnology*. 2005;16(10):2346–2353.
22. Pal S., Tak Y.K., Song J.M. Does the antibacterial activity of silver nanoparticles depend on the shape of the nanoparticle? *Applied and Environmental Microbiology*. 2007;73(6):1712–1720.
23. Lok C.N., Ho C.M., Chen R., et al. Silver nanoparticles: Partial oxidation and antibacterial activities. *Journal of Biological Inorganic Chemistry*. 2007;12(4):527–534.
24. Marambio-Jones C., Hoek E.M.V. A review of the antibacterial effects of silver nanomaterials and potential implications for human health and the environment. *Journal of Nanoparticle Research*. 2010;12(5):1531–1551.
25. Reidy B., Haase A., Luch A., Dawson K.A., Lynch I. Mechanisms of silver nanoparticle release, transformation and toxicity: A critical review. *Particle and Fibre Toxicology*. 2013;10:18.
26. Prabhu S., Poulose E.K. Silver nanoparticles: mechanism of antimicrobial action, synthesis, medical applications, and toxicity effects. *International Nano Letters*. 2012;2:32.

ISSN NO: 2770-2936
January, 2026

27. Kumar A., Vemula P.K., Ajayan P.M., John G. Silver-nanoparticle-embedded antimicrobial paints based on vegetable oil. *Nature Materials*. 2008;7(3):236–241.
28. Rai M., Deshmukh S.D., Ingle A.P., Gade A.K. Silver nanoparticles: the powerful nanoweapon against multidrug-resistant bacteria. *Journal of Applied Microbiology*. 2012;112(5):841–852.
29. Chaloupka K., Malam Y., Seifalian A.M. Nanosilver as a new generation of nanoproduct in biomedical applications. *Trends in Biotechnology*. 2010;28(11):580–588.
30. Zhang T., Wang L., Chen Q., Chen C. Cytotoxic potential of silver nanoparticles. *Yonsei Medical Journal*. 2014;55(2):283–291.