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Nanosilver: A magic particles for human welfare

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Abstract
Nanosilver consists of silver particles that have very small sizes, usually ranging from 1 to 100 nanometers. Nanosilver differs from regular silver in its characteristics, such as more surface area and reactivity, which make it beneficial for many purposes in different domains, such as medicine, environment, and industry. This article gives a comprehensive overview of the characteristics, production, uses, risks, and environmental effects of nanosilver. It explains the physical and chemical characteristics of nanosilver, including its pros and cons compared to normal silver. It also describes various ways of producing nanosilver, and factors that influence its production. It shows the various uses of nanosilver, including its role as an antibacterial agent in healthcare, clothing, and food storage; a catalyst in organic chemistry and water treatment; and in electronic and optical uses such as detectors and screens. It also looks at the risks and environmental effects of nanosilver, including the ways of toxicity and the impacts on water animals and soil bacteria. It talks about the current rules and standards for the use of nanosilver. It also discusses future directions and challenges in the development and use of nanosilver, including new uses, challenges in size, safety, and price, and possible solutions to these challenges. This article gives a complete understanding of the characteristics, uses, and challenges related to nanosilver, and emphasizes the need for more research and development to ensure its safe and effective use.

Keywords: Nanosilver, synthesis, applications, toxicity, environmental impact, antimicrobial agent, regulations, challenges, emerging applications

Introduction

Silver has been used for its antimicrobial properties for thousands of years, dating back to ancient civilizations such as the Greeks and Egyptians who used silver containers to preserve water and other liquids. In the 19th century, silver nitrate was used to prevent eye infections in newborns, and silver sulfadiazine became a widely used topical antibacterial agent for wound healing in the 20th century. The development of nanotechnology in the late 20th century led to the production of nanosilver with unique properties, including a high surface area to volume ratio, enhanced reactivity, and catalytic activity. The first nanosilver particles were produced in the 1990s using a variety of methods, including chemical reduction, sol-gel methods, and physical methods such as laser ablation and ball milling [5, 66].

Nanosilver, a form of silver with a size range of 1-100 nm, has gained significant attention due to its unique physical and chemical properties. Nanosilver is highly reactive, possesses high surface area to volume ratio, and exhibits enhanced catalytic, antimicrobial, electronic, and optical properties compared to bulk silver. As a result, nanosilver has found applications in diverse fields, including biomedicine, environmental science, and electronics. Several studies have reported the antimicrobial properties of nanosilver against various microorganisms, including bacteria, viruses, and fungi [20, 29, 6, 31, 4]. For example, different studies demonstrated the significant antimicrobial activity of nanosilver against multidrug-resistant bacteria [2]. Similarly, a recent study reported the effectiveness of nanosilver in controlling viral infections [61]. Nanosilver has also been extensively investigated as a catalyst in various chemical reactions, including organic synthesis and wastewater treatment. The high surface area and reactivity of nanosilver enable efficient catalytic activity, leading to improved reaction rates and selectivity [24, 8, 28].

A remarkable study highlighted the potential of nanosilver as a catalyst for the synthesis of fine chemicals. Despite the promising applications of nanosilver, concerns regarding its toxicity and environmental impact have been raised. Several studies have reported the toxic effects of nanosilver on various organisms, including humans, and its potential environmental impact, such as the accumulation in soil and aquatic ecosystems.

Therefore, the development of safe and effective nanosilver-based products is critical. In this review, provide an overview of the properties, synthesis, applications, toxicity, and environmental impact of nanosilver, highlighting recent studies and emerging applications. We also discuss the current regulations and guidelines for the use of nanosilver and identify the challenges and future directions in the development and use of nanosilver [80].

Green synthesis of nanosilver

Table 1: Microbe-mediated silver nanoparticles synthesis

Name of microbes	Type of microbes	Size (nm)	References
Candida albicans	Fungi	60–80	[19]
Vibrio alginolyticus	Bacteria	50–100	[74]
Pseudomonas stutzeri AG259	Bacteria	200	[43]
Streptacidiphilus durhamensis	Actinomycetes	8–48	[16]
Schizophyllum radiatum,	Fungi	-	[67]
Candida utilis NCIM 3469	Yeast	20–80	[75]
Candida lusitaniae	Yeast	2–10	[25]
Aspergillus terreus	Fungi	1-20	[45]
Pleurotus ostreatus	Fungi	8-50	[22]
Penicillium fellutanum	Fungi	10-50	[26]
Bacillus thuringiensis	Bacteria	44-143	[11]
Bacillus mojavensis	Bacteria	105	[38]
Bacillus brevis	Bacteria	41-68	[63]
Saccharomyces uvarum HA-NY3	Yeast	12-21	[7]
Pseudomonas aeruginosa	Bacteria	60-70	[10]
Solibacillus isronensis	Bacteria	80-120	[68]
Streptomyces zaomyceticus Oc-5	Actinomycetes	11.32-36.72	[30]
Streptomyces rochei	Actinomycetes	5-40	[47]
Streptomyces Hirsutus Strain SNPGA-8	Actinomycetes	18.99	[56]

Table 2: Plant-mediated silver nanoparticles

Name of plant	Parts used	Size (nm)	References
Andrographis paniculata	Leaves	40–60	[70]
Brassica oleracea	Arial parts	36	[71]
Alternanthera dentate	Leaves	50–100	[64]
Coffea arabica	Seeds	20, 30	[23]
Artemisia princeps	Arial parts	10-40	[35]
Antigonon leptopus	Whole plant	10-60	[32]
Pistacia terebinthus	Whole plant	32	[50]
Pteris vittata	Whole plant	17.2	[41]
Azadirachta indica	Leaves	40	[73]
Aloe vera	Arial parts	20.9	[49]
Stevia rebaudiana	Arial parts	50-100	[72]
Cassia tora	Seeds	60.78	[51]

Since then, nanosilver has gained significant attention and has been studied extensively due to its unique properties and potential applications. Nanosilver has found applications in various fields, including biomedicine, environmental science, and electronics, and has been used in products such as wound dressings, water treatment systems, and electronic devices. However, concerns about the potential toxicity and environmental impact of nanosilver have also emerged, leading to regulations and guidelines for its use. Nevertheless, the ongoing research and development of nanosilver hold promise for new and emerging applications in various fields.

Applications of nanosilver

Applications of nanosilver have been explored in various fields due to its unique physical and chemical properties.

Biomedicine

Nanosilver has been extensively studied as an antimicrobial agent for wound dressings, implants, and other medical devices. It has also been explored for its potential in cancer therapy, drug delivery, and imaging. Studies have reported the effectiveness of nanosilver against various microorganisms, including bacteria, viruses, and fungi [15, 55, 76].

Environmental science

Nanosilver has shown promise in environmental applications, such as water treatment, air purification, and soil remediation. Studies have reported the use of nanosilver for removing pollutants, such as heavy metals and organic compounds, from water and air [12, 60, 28].

Electronics

Nanosilver has been explored for its potential in electronic applications, such as conductive inks, transparent conductive films, and sensors. Studies have reported the use of nanosilver for producing highly conductive and flexible electronic devices [48, 14, 78, 39].

Catalysis

Nanosilver has shown promise as a catalyst for various chemical reactions, including organic synthesis and wastewater treatment. Studies have reported the use of nanosilver for producing fine chemicals and treating wastewater [18, 13, 33].

Food industry

Nanosilver has been investigated for its potential in food preservation and packaging. Studies have reported the use of nanosilver for inhibiting the growth of microorganisms in food and extending its shelf life [44, 17, 1, 21].

Textile industry

Nanosilver has been explored for its potential in producing antibacterial and antifungal textiles. Studies have reported the use of nanosilver for producing textiles with enhanced antimicrobial properties [37].

Emerging Applications

Nanosilver has shown promise in various emerging applications, including drug delivery, cancer therapy, and agriculture. For example, nanosilver has been used as a carrier for targeted drug delivery and as a potential anticancer agent [57, 77, 40, 34].

Agriculture

Nanosilver has the potential to revolutionize the agricultural industry by improving crop yield and reducing the use of pesticides. Studies have shown that nanosilver can enhance plant growth, increase resistance to pathogens and pests, and improve nutrient uptake [65, 42, 3, 36]. Nanosilver can also be used to develop eco-friendly pesticides that are less harmful to the environment.

Energy storage

Nanosilver has been used in the development of advanced energy storage devices such as batteries and super capacitors. Nanosilver coatings on electrodes have been shown to improve the performance and stability of energy storage devices [58, 9].

Overall, the emerging applications of nanosilver are promising and have the potential to make a significant impact in various fields. However, it is essential to ensure the safe and responsible use of nanosilver to minimize potential risks to human health and the environment.

Toxicity environmental impact and limitations of nanosilver

Nanosilver has gained significant attention due to its widespread use in various applications. However, the potential toxicity and environmental impact of nanosilver have also been a subject of concern. Several studies have reported adverse effects of nanosilver on human health and the environment.

Nanosilver can enter the body through inhalation, ingestion, or skin contact, and its toxicity can depend on various factors such as size, shape, surface charge, and coating. Studies have shown that nanosilver can cause DNA damage, cell death, oxidative stress, and inflammation [27, 79]. Moreover, nanosilver can also affect the function of organs such as the liver, kidney, and lung [52, 69, 59, 53].

Challenges and Considerations in the Safe and Sustainable Use of Nanosilver: Towards Standardized Regulations and Public Awareness

To minimize the potential toxicity and environmental impact of nanosilver, several studies have focused on developing sustainable and safe nanosilver products and processes. Such efforts include the use of biodegradable and eco-friendly materials for nanosilver synthesis, the development of efficient nanosilver recovery and recycling methods, and the implementation of regulations and guidelines for the safe use and disposal of nanosilver-containing products.

Currently, there is a lack of standardized regulations for the production, labelling and disposal of nanosilver products. The use of nanosilver in consumer products is largely unregulated, and there is a need for international guidelines to ensure its safe and responsible use.

The production of nanosilver is often expensive and requires specialized equipment and expertise. This can limit its widespread use, especially in developing countries.

The stability and reproducibility of nanosilver products can vary depending on the production method and conditions. This can lead to inconsistencies in the performance and efficacy of nanosilver products, making it challenging to develop reliable and consistent applications.

There is a lack of public awareness and understanding of nanosilver, leading to misconceptions and mistrust about its safety and efficacy. Therefore, it is essential to educate the public about the benefits and potential risks of nanosilver and address any concerns they may have.

Overall, the development and use of nanosilver present significant challenges that need to be addressed to ensure its safe and responsible use. Future research should focus on developing cost-effective and sustainable production methods, improving the stability and reproducibility of nanosilver products, and developing standardized regulations and guidelines for its production, labelling and disposal.

Conclusion

In conclusion, nanosilver particles have been shown to possess antibacterial, antifungal, antiviral, and anti-inflammatory properties. The mechanisms of action of nanosilver particles involve ROS generation, disruption of the bacterial cell membrane, binding to bacterial proteins and DNA, and interference with biofilm formation. These mechanisms collectively lead to bacterial cell death, making nanosilver particles a promising alternative to conventional antibiotics. However, further research is needed to fully understand the potential toxicity and environmental impact of nanosilver particles, as well as their long-term effectiveness in clinical settings. Overall, nanosilver particles hold great promise as a new generation of antibacterial agents.

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