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The Effect of Silver Nanoparticles on the Biofilm of *Escherichia coli*

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تأثير جسيمات الفضة النانوية على الغشاء الحيوي في بكتيريا *Escherichia coli*

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ABSTRACT

Nanotechnology has emerged as a new, as a new approach to tackling antimicrobial resistance. AgNPs have been demonstrated. AgNPs have received extensive attention requiring their exceptional properties, such as chemical stability and of high quality conductivity. Unlike other metal nanoparticles, silver is non-toxic and harmless to the human body at low concentrations. These pathogenic bacteria exhibit several virulence factors, including the cytotoxic necrosis factor (colicin) and surface structures such as flagella and a capsule. They also possess cilia, which help them adhere to host tissues, enabling them to form biofilms. Given the importance of biofilms in the development of pathological infections and increased drug resistance, AgNPs have proven effective in inhibiting biofilm formation and secondary reactions. Scientists have been searching for a suitable method to control and prevent the growth of biofilms, given their good compatibility with a mixture of AgNPs. Studies have shown that the diameter of the nanoparticles affects the bacteria.

Conclusion

Antibiotic resistance patterns raise concerns about the emergence and resurgence of multidrug-resistant pathogens. Developing or modifying antimicrobial compounds to improve their ability to kill bacteria is a modern priority. Nanotechnology provides effective principles for improving and developing nanostructures with promising applications in various fields. These silver nanoparticles have proven effective as weapons against potent biofilm producers, such as *E. coli*, which causes urinary tract infections. These particles can also be used synergistically with certain antibiotics, increasing the effectiveness of the antibiotic against bacterial resistance.

Key words: **silver nanoparticles**, ***Escherichia coli* , Biofilm**.

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INTRODUCTION

1- the Nano Era Nanotechnology silver nanoparticles

Nanotechnology has received significant attention, as it is considered a modern technology that still requires extensive research and study. In our coming era, the nano era, this technology will have a significant impact on many areas of industrial, medical, and agricultural life, as well as transportation, aviation, space research, water technology, and many other vital fields **[1]**. Nanoparticle sizes range from 1 to 100 nanometers, increasing their ability to interact with target tissues and cells .Nanoparticles have recently been used as drug delivery vehicles due to their distinctive properties, such as their small size and large surface area relative to their volume. These particles have the ability to easily penetrate biological barriers and membranes to reach hard-to-reach areas. **[2].** Nanotechnology mentions any technology that is executed at the nan scale, that matter is restructured at the atomic and molecular levels with a size within the scope of (1-100nm) **[3]**. Silver nanoparticles, in particular, have promising applications in nanotechnology and medicine, where their bactericidal activity against bacterial infections has been exhibited, Nanotechnology has been developed as a new strategy in the field of antimicrobials to eliminate resistant microbes. Metallic nanopar-ticles, such as those made of silver, copper, platinum, and gold, have antimicrobial properties that fight fungi, bacteria, and various diseases **[4].** Silver is also non-toxic and harmless to the human body at low concentrations, unlike other metal nanoparticles. Due to the resistance to antibiotics developed by bacterial species that cause infections it has become necessary to search for suitable alternatives to kill these species. The antibacterial effect of silver depends on the silver ion, and silver ions are able By reducing the electron density inside the bacteria, a new large gap was formed between the cell membrane and the cell wall. It has been shown that the cell membrane sometimes dissolves completely, leading to a leak inside the cell. It has also been shown that silver ions bind to DNA molecules, causing mutations **[5]**. Silver nanoparticles are currentlyused to control bacterial growth in a variety of applications, as antiseptic and antibacterial medicine, dental materials, burn wound treatment and catheterization. Ag ions and silver-based compounds are known to be highly toxic to microorganisms, exhibiting a potent biocide effect against Up to 12 manners of bacteria **[6]**.

2- The ability of *E. coli* to produce biofilm production

Escherichia coli has the ability to opportunistically infect the body wherever the opportunity exists, causing many diseases. It is considered one of the most important species of Enterobacte-riaceae family and is naturally endemic to the human digestive tract. It is also found in the intestines of animals and spreads in the environment, causing contamination of water, milk and food, and is an indicator of fecal contamination of water **[7].** They live naturally in the intestines of humans and animals, and they are opportunistic pathogens which cause many diseases such as meningitis,diarrhea, bacteremia,sepsis, and urinary tract infections [8]. This bacteria is pathogenic due to the presence of numerous virulence factors. including its possession of the cytotoxic necrotizing factor (colisin), and its possession of surface structures such as flagella and capsules. It also possesses pili, which assist it attach to the host tissues, giving it the capability to form a biofilm **[9]**.The formation of the three-dimensional construction of biofilm is a several step process and involves adsorption, adhesion, Micro-colony formation, maturation and dispersion (Figure 1). The solid–liquid convergence of a biofilm surface with an aqueous medium (such as water or blood) provides absolute conditions for microbial attachment and

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growth. The Close association of cells in a biofilm colony creates conditions that encourage the development of gradients in nutrition availability, genes exchange and quorum sensing (QS). **[10].** The formation of biofilms enables unicellular organisms to organize temporary communal survival. concentrated resources that are important for these organisms. such as nutrients and genetic exchange opportunities. Although the general stages leading to biofilm formation are similar across pathogens, the adhesive fibers, proteins, nucleic acid, and exopolysaccharide material associated with a biofilm can be distinct in a species or even strain specific manner. Moreover, the architecture, kinetics, microbe interactions (in polymicrobial biofilms) and regulatory components controlling biofilm formation vary from pathogen to pathogen. **[11].**

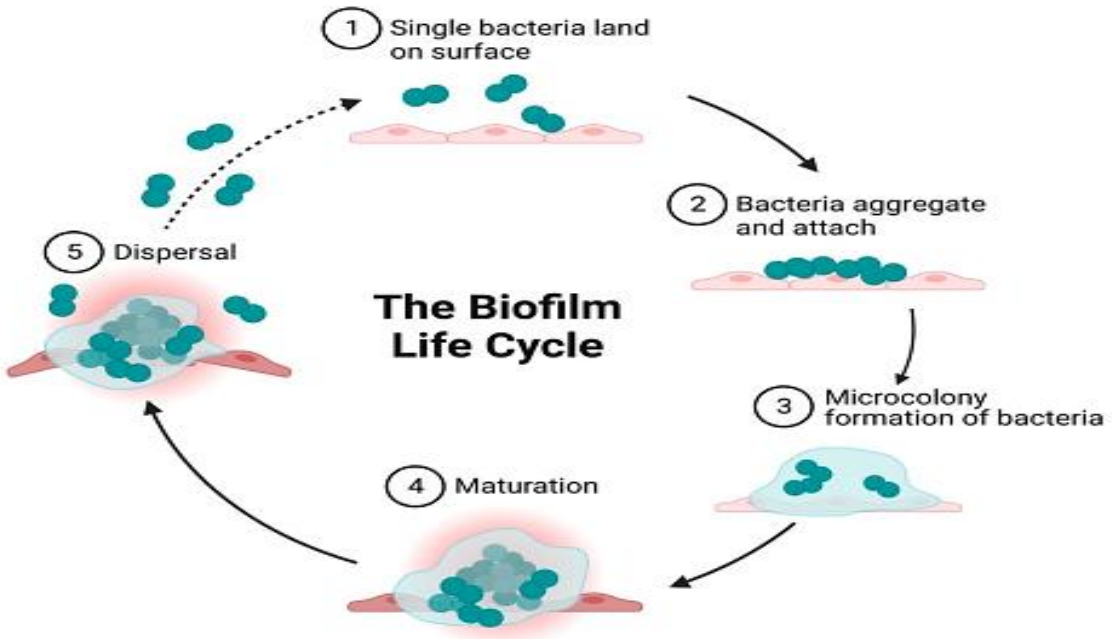

Figure 1: show the growth cycle of bacteria that form a biofilm on a solid surface.1- Reversible adhesion of a single planktonic cell to surfaces. Adhesion is influenced by repulsive and attractive forces resulting from nutrient concentrations, pH, surface and temperature.2- Bacterial accumulation and irreversible adhesion to surfaces.3- growth of a complex multilayered extracellular matrix of biomolecules.4-Maturation of biofilms and their asset of a three-dimensional structure upon reaching maturity depends on the components of the extracellular matrix.5-fully developed biofilms completely detach and subsequently form biofilms at other sites. [11]

3- Impact of silver nanoparticles on biofilm of *Escherichia coli*

3-1 The concept of nanotechnology:

The concept of Nano means one part in a billion. The Nano is about 80,000 times small-scale than the diameter of a hair.The distance is measured in one billionth of a meter, which is equivalent to ten times the atomic measurement unit known as the angstrom, The term nanotechnology is also used. Meaning, it is nanomaterial technology, microscopic technology, or miniature technology **[12]**. The word 'nano' advance from the Greek word 'dwarf', which meaning a billionth part of the total. Nanotec-hnology consists of employing nanostructures in devices and tools of Nano scale dimensions. It is important to know that the Nano scale is very, very small. **[13].**The scheme of nanotechnology is to arrange differently the atoms that make up the materials in their correct position, and whenever the atomic arrangement of the material modification, the resultant of it changes to a great extent. In other words, products manufactured

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from atoms are manufactured, and the characteristic of these products depend on how these atoms are arranged. If they organize coal in a certain way, they can get diamonds. What science is working on now is changing the method of arranging basedon nano scale from one material to another. By solving this puzzle, what scientists dreamed of centuries ago is converting cheap metals into gold. **[14].**

3-2 Importance of nanoparticles

The great interest in nanoparticles in recent years has been a result of their distinctive and impressive properties. When a substance becomes small and its dimensions on a nan scale are reduced by 100 nanometers. it forms a nanoparticle, it exhibits new physical and chemical properties, as its characteristic be different very significantly from its known properties if it were in its natural dimensions size of the same material, and this property made nanoparticles "A new scientific miracle" since the properties known to us about a substance will differ completely when this substance is a Nanoparticle. For example, insulating materials become conductors when they become nanoparticles, and conductors also become insulators when they become nanoparticles, and so on have many amazing behaviors and properties**[15]**. The reasons for this change in the physical and chemical properties and features of nanoparticles are due to two main reasons: Increasing the surface area: Increasing the surface area of the substance leads to an increase in the reactivity of the substance, meaning that the substance becomes highly chemically active as its reactive surface area increases. Since increasing the surface area means increasing the number of atoms present on the surface, the surface atoms of any substance are responsible for the chemical reaction process with other atoms because they have unbound electrons. **[16].**while the atoms inside the material are more bound and therefore do not participate in the chemical reaction process. Therefore, when As the material becomes smaller, its surface area increases, which means an increase in the percentage of atoms present on the surface of the material that are in high energy states, which helps in increasing the interaction of these atoms with the atoms of their neighboring materials. Second: Quantum effect: Quantum effects begin to control the behavior of matter at the Nano scale, affecting its optical, electrical, magnetic, and other properties. For example: One of the distinctive properties of nanoparticles is the ability to change color, when the size and shapes of these particles change. The phenomenon is found in some elements, such as the element gold. It is known that the metal gold is chemically stable, so it does not interact directly with materials, but when we obtain nanoparticles of gold, **[17].** Nano gold particles, and as these particles are reduced to a smaller and smaller size, that is, when the dimensions of these particles change from 100 nanometers to smaller dimensions such as 80 nm, 60 nm, 40 nm and so on. The color of gold known to us changes to other colors that differ according to the different dimensions of these particles. Gold nanoparticles interact with infrared radiation and convert it into heat, and gold in its normal state (bulk) does not interact with electromagnetic radiation **[18].**

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3-3 Nanotechnology applications.

Nanotechnology is a philosophy and a method that is essentially based on human dominance and the development of its capabilities in changing the structural structures of engineering materials and bypassing the classics of physics and chemistry and their traditional theories in order to raise the level of performance of the devices that contain these materials, in order to achieve a breakthrough in applications and add innovative and new dimensions in various current industries. And futuristic **[19]**. Nanoparticles possess unique biological, chemical, and physical properties, as well as antiviral, anti-inflammatory, antibacterial, and activities. Silver nanoparticles are essential for the development and application of novel biomedical approaches. Silvernanoparticles have recently been the subject of extensive studies, The specific fluorescence characteristic of silver nanoparticles also makes them suitable for detection and dose optimization in X-ray applications.. **[20], [21]** . Gold nanoparticles are characterized by their ability to absorb light and convert it into heat, so the tumor is injected with them, which destroys the cell. infected without affecting neighboring cells. Nanotechnology has been used in the rapid and accurate detection of viruses, dilating vessels, and improving and enhancing the antibacterial activity of textile fibers. Studies have also talked about the topics of immune response and nan medicines that can be used to detect diseases in early stages **[22]**.

3-5 Silver nanoparticles

Nanotechnology has appeared as a new approach in the field of antimicrobials, sight to combat resistant microbes. Nanoparticles such as platinum, copper, gold and silver contain antimicrobials that restrain bacteria that cause different diseases . Silver nanoparticle technology has a bright future in both nanotechnology and medicine. Their bactericidal properties, additionally their anti-viral and anti-fungal properties, construct them highly effective against a variety of diseases. **[23]**. nonmetals, silver nanoparticles have been used since the 1880s. for the reason that silver has broad-spectrum antimicrobialactivityagainsta wide range of microorganisms. Silver nanoparticles have received limitless attention due to their exceptional properties such as chemical stability, catalytic activity, Silver is non-toxic and harmless to the human body at low concentrations. It also has excellent conductivity, unlike other metal nanoparticles. Most importantly, it is antimicrobial. **[24]**.Silver nanoparticlesarecurrently used tocontrolbacterialgrowth in avariety of applications, as antiseptic and antibacterial medicine, dental materials, burn wound treatment and catheterization. Silver ions and silver construct compounds are recognized to be highly toxic to microorganisms, showing a strong biocide effect on Up to 12 types of bacteria. They have also been widely used as antibacterial agents in the health and food storage products, as well as in a number of environmental applications, as products made from silver nanoparticles have been approved by a group of accredited bodies, including the US Food and DrugAdminis-tration, the KoreaChemical Industry testing and Research Institute, US Environmental Protection Agency **[25].**

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3-5 Inhibition of biofilm activity by silver nanoparticles.

Bacteria in biofilms show a high degree of resistance to antibacterial agents and the host immune system. The resistance of membrane-forming bacteria to antibiotics is on average higher thanthat of free-living bacteria **[26].** The life membrane helps bacteria survive in harsh conditions inside the host and is responsible for chronic and incurable infections, including endocarditis, cystic fibrosis, otitis media, tooth decay, eye infections, and others **[27].** Given the importance of the biofilm in the occurrence of disease infection and in increasing drug resistance, the effectiveness of inhibiting the construction of the biofilm and secondary reactions by silver nanoparticles was revealed. Scientists searched for a suitable method to control and prevent the growth of the biofilm, and the silver nanoparticles ranged between (1-100). nm, with the presence of physicochemical substances and biological and optical properties affect the growth of the bacterial membrane (White sides). In general, the combination treatment of antibiotics (metals chelating agents novel cephalosporin, halogens, phage therapy) and silver nanoparticles uses this group as a means against membrane growth. life of bacteria **[28],[29].**studied the effects of silver nanoparticles alone and also in combination with several antibiotics, and concluded that silver nanoparticles alone inhibited the biofilm within 24 hours, as well as good compatibility with a combination of silver nanoparticles and antibiotics to inhibit the biofilm, The high surface-to volume ratio of nanoparticles plays an important role in inhibiting bacterial growth. Studies have shown that the diameter of the nanoparticle affects the bactericidal action. Therefore, choosing an effective formulation method to control the size of the antibacterial has more antibiotic activity than the larger particles, and the activity of the silver particles. Small nanoparticles are more triangular in shape than spherical **[30].**In general, silver nanoparticles are more active on negative bacteria, of Gram-positive bacteria, the resistance of bacteria (Gram-positive) to silver nanop-articles may be due to the synthesis of thick peptidoglycan in the Gram-positive cell wall **[30].** Some researchers believe that the lipopolysaccharide found in bacteria (Gram negative) traps the positively charged silver nanoparticles and leads to the nanoparticles being blocked. As aresult, silver nanoparticles bind to the surface of cell membranes and can disrupt the membrane's performance, penetrate the cell and release silver ions into the cell **[32].** Silver nanoparticles can themselves butcher bacteria, including being able to release silver ions. after they adhere to the cell surface. Silver nanoparticles can assemble in the pits that form on the cell wall. The silver nanoparticles accumulated can cause cell membrane denaturation. Because of their nan scale size ,Silver nanoparticles also have the potential to penetrate bacterial cell walls and subsequently change the construction of the cell membrane. The denaturation of cytoplasmic membrane can disrupt organelles, and even result in cell lysis. In addition, silver nanoparticles can be complicated in bacterial signal transduction. Nanoparticles can dephosphorylate tyrosine residueson peptide substrates, and bacterial signal transduction is affected by the phosphorylation of protein substrates. Disrupting signal transduction can lead to cell death and termination of cell proliferation. **[33], [34].**

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CONCLUSIONS

Antibiotic resistance patterns raise concerns about the emergence and resurgence of multidrug-resistant pathogens. Developing or modifying antimicrobial compounds to improve their ability to kill bacteria is a modern priority. Nanotechnology provides effective principles for improving and developing nanostructures with promising applications in various fields. These silver nanoparticles have proven effective as weapons against potent biofilm producers, such as *E. coli*, which causes urinary tract infections. These particles can also be used synergistically with certain antibiotics, increasing the effectiveness of the antibiotic against bacterial resistance.

Conflict of interests.

There is no conflict of interests.

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الخلاصة .

المقدمة . طُوّرت تقنية النانو كاستراتيجية جديدة في مجال مقاومة مضادات الميكروبات. وقد ثبتت فعالية جسيمات الفضة النانوية، وقد حظيت جسيمات الفضة النانوية باهتمام واسع النطاق نظرًا لخصائصها الاستثنائية، مثل الاستقرار الكيميائي والتوصيلية الممتازة. وعلى عكس الجسيمات النانوية المعدنية الأخرى، فإن الفضة غير سامة وغير ضارة لجسم الإنسان بتركيزات منخفضة. تُظهر هذه البكتيريا المسببة للأمراض العديد من عوامل الضراوة، بما في ذلك عامل النخر السام للخلايا (الكوليسين) وتراكيب سطحية مثل الأسواط والكبسولة. كما تمتلك أهدابًا تساعدها على الالتصاق بأنسجة الجسم المضيف، مما يُمكّنها من تكوين أغشية حيوية. ونظرًا لأهمية الأغشية الحيوية في تطور العدوى المرضية وزيادة مقاومة الأدوية، فقد أثبتت جسيمات الفضة النانوية فعاليتها في تثبيط تكوين الأغشية الحيوية والتفاعلات الثانوية. وقد بحث العلماء عن طريقة مناسبة للسيطرة على نمو الأغشية الحيوية ومنعه، نظرًا لتوافقها الجيد مع خليط من جسيمات الفضة النانوية. وقد أظهرت الدراسات أن قطر الجسيمات النانوية يؤثر على البكتيريا.

الإستنتاجات:

تُثير أنماط مقاومة المضادات الحيوية مخاوف بشأن ظهور وعودة مسببات الأمراض المقاومة للأدوية المتعددة. ويُعدّ تطوير أو تعديل مركبات مضادة للميكروبات لتحسين قدرتها على القضاء على البكتيريا أولويةً حديثة. تُوفر تقنية النانو مبادئ فعّالة لتحسين وتطوير البنى النانوية ذات التطبيقات الواعدة في مجالات مُختلفة. وقد أثبتت جسيمات الفضة النانوية فعاليتها كأسلحة ضد مُنتجات الأغشية الحيوية القوية، مثل الإشريكية القولونية، المُسببة لالتهابات المسالك البولية. كما يُمكن استخدام هذه الجسيمات بتآزر مع بعض المضادات الحيوية، مما يزيد من فعالية المضاد الحيوي ضد مقاومة البكتيريا.

الكلمات المفتاحية : جسيمات الفضة النانوية، الإشريكية القولونية، الأغشية الحيوية .