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ANTIMICROBIAL ACTIVITY OF SILVER NANOPARTICLES AGAINST *SALMONELLA ENTERITIDIS*

Farkhanda[1,2*], Umbreen Shaheen[1], Abdul Samad[2], Farha Manzoor [1], Sidra Aftab[1], Sana Saeed Ahmad[1], Shoaib Ahmad Malik[3]

[1]**Department of Zoology** University of Balochistan, Quetta, Pakistan

[2]**Center for Advanced Studies in Vaccinology and Biotechnology (CASVAB),** University of Balochistan, Quetta, Pakistan

[3]**Department of Biochemistry, Sargodha Medical College,** University of Sargodha, Sargodha, Pakistan

***Corresponding Author:** Farkhanda E. mail: farkhandaf7@gmail.com

Abstract

Bio-Nanotechnology has promptly been the mounting discipline of research which entails the manufacture and advancement of diverse nanomaterials. Silver utilization is as old as the human civilization but the modifications in silver and its salts are recently identified. Whereas the silver nanoparticles have attained a great interest of researchers due to their antimicrobial, antifungal properties. Silver nanoparticles penetrate into bacterial cell and interact with the molecular structures of the cell thus inhibiting their growth. Smaller sized silver nanoparticles are seemed to be more effective than the bigger ones. In addition silver nanoparticles have wide range of biomedical applications and these are also used in packaging of edibles to save them from deterioration, decomposition and microbial invasion. Salmonellosis is a foodborne disease that is caused by Salmonella enteritidis found in the raw food. More than 200 species out of 2000 species of salmonella are responsible for causing severe diseases in man. Though antibiotic resistant bacteria is known to be a major health concern in this world. Silver nanoparticles have been utilized to check the sensitivity of concerned organism (Salmonella enteritidis) by many researchers which are highlighted in this review.
Keywords: *Bio-nanotechnology, Silver Nanoparticles, antimicrobial.*

INTRODUCTION

Nanotechnology can be defined as "handling of matters at nanoscale (1). It is the study of very small structures that ranges from 0.1 to 100 nm in size (2). It is concerned with construction, management and utilization of materials that varies in size in nanometers (3). Actually NPs are constituent parts with a surrounding interface layer that range in size from 1 to 100 nanometers (nm). The interface layer is a crucial component of nanoscale materials, as it influences all of its features. Ions, inorganic, and organic molecules often make up the interfacial layer. Stabilizers, capping, surface ligands and surface passivation means are the organic compounds that cover inorganic nanoparticles (4).

Bio nanotechnology is the new field of life science and technology that will alter the way we use materials in the twenty-first century. We shall be supplanted by extremely efficient and eco-friendly nanotechnologies, which will replace the comparatively rough and artless technologies on which we now count on (5). The progresses of new-fangled investigational and speculative techniques for exploration, as well as the discovery of novel materials, processes and phenomena at the nanoscale provide new potential for the improvement of inventive Nano-systems and Nano-structured materials (6). Nanotechnology has helped to find an instant predicament on programs of strategy creators and industry leaders (7). Nanotechnology is essential since it takes up fewer space, it is quicker, utilizes a smaller amount of material, and lesser energy. It also has novel features, phenomena and it is the most efficient length scale for production, it intersects life and non-living systems (8).

A vast range of ultra-small materials, such as, ceramic ware, micro porous matters and metal oxides, as well as a wide range of processing technologies, such as procedures that hire prefabrication on a molecular size, are either in practice or being dressed on behalf of mercantile-scale usage. Additional instances, which are still in the works, are centered on pollution prevention and treatment (9).

It's a new field of study with a wide range of applications in science and technology, particularly in the development of novel materials. Nanoparticles are created with unique features that make them appealing to materials scientists and biologists. Silver nanoparticles have long been one of the most popular nanoparticles. In the last few decades, there have been a lot of things that have been studied (10).

NANOPARTICLES

Particles with nanometer scale of less than 100 nm are referred to as nanoparticles and this classification seats these particles in the similar magnitude as pulverized atoms (airborne granules) and as a subset of colloidal particles (11).

Nanoparticles and nanostructured materials are an active research subject and a growing techno-economic sector with applications in a wide range of fields. Because of their tunable physicochemical features such as wettability, melting point, thermal and electrical conductivity, catalytic activity, light scattering and absorption, nanoparticles and nanostructured materials have acquired significance in technological breakthroughs over their bulk complements. A nanometer (nm) is a unit of length defined by the International System of Units (SI). In theory, Nanomaterials are materials with a length of 1–1000 nm in at least one dimension; nonetheless, these are most often described as having a diameter of 1–100 nm (12).

Nanoparticles are the Nano-objects with three minute dimensions arranged outside. When the extensive and diminutive axis lengths of a Nano-object differ, the terminologies nan-rod or Nano-plate is utilized as an alternative of nanoparticle where as any nanoscale material with intrinsic or exterior nanoscale features (13).

Nanoparticles can be categorized on the basis of their shapes e.g. Nano rod, whisker, nanotubes *etc.*, furthermore depending upon shape and size silver nanoparticle has distinct magnetic and optical properties due to which it can be used as an antimicrobial agent, bio sensing, electronic devices and in cosmetics etc. However, nanomaterials are also being used in therapeutic chemistry, atomic physics, and all other known fields (14). IPod Nano is the product of nanoparticle that is used as a storage device (15). Nano gels, Nano emulsions, liposomes and various other Nano size ranged materials are employed for cellular drug delivery and imaging (16).

SILVER NANOPARTICLES

Due to their exceptional antibacterial properties, silver nanoparticles (AgNPs) have gotten a lot of interest during the last several decades all over the world (17-20). Silver nanoparticles (AgNPs) are the most commercialized nanomaterial because of their well-established broad spectrum antimicrobial properties and their lower tendency to induce microbial resistance (21). Silver nanoparticles which are the most frequently used particles and predominantly aiding as biocidal agents in the field of medicine (22).

As they have distinctive optical characteristics, AgNPs are progressively used in many industries, which include medication, health care, foodstuff, customer goods and chattels, and industry. Beside these physical and chemical properties, they are greatly conductive to electricity (23-24). Due to high surface-to-volume ratio, Nano sized metallic particles are unique in that they can significantly affect physical, chemical, and biological properties; as a result, these nanoparticles have been used for a variety of applications (25-26).

APPLOCATIONS OF AgNPs

For about 2,000 years, silver has been known as antiseptic material for burnt injuries among ancient Greeks (27). These are also used for catalyzing chemical reactions, Raman imaging, and antimicrobial sterilization (28) Silver nanoparticles are being used as antimicrobial for eradicating bacteria, fungi and viruses (29).

AgNPs are employed broadly in medical, food packaging, fabric coats, and a number of environmental applications as antibacterial agents. It is worth noticing, after decades of use, there's still no conclusive evidence of silver's toxicity (30).

AgNPs have been used as antibacterial agents in a variety of applications, including cleaning medical devices from home appliances to water purification (31). As antioxidants and anti reflectantes, NMs are used in cosmetic products and skincare products (32). NPs have been widely used in commercial items ranging from cosmetics to paints, in addition to cosmetics (33). Titanium oxide nanoparticles (NPs) with a diameter greater than 100 nm are widely used as a white pigment in cosmetic lotions and sunscreens (34).

AgNPs have also been employed in a variety of products such as air sanitizing aerosols, sanitary towels, food storage boxes, cleansers, and mouthwashes (35). Many nanoparticles are being studied as additions in skincare products. Despite the growing popularity of items containing various types of nanomaterials, little is known about their potential for harm to humans. AgNPs were shown to have a size, according to numerous investigations; shape, as well as a dose-dependent increase in cytotoxicity to asbestos is more harmful to human and animal cells. Other NPs found in consumer products have unknown dangers that are still being investigated (36). Because of their antibacterial properties, metals like silver and copper have been used by humans for millennia, and their applications in consumer products are currently being investigated. Shampoo, Textiles, hygiene goods, and other products medications, AgNPs are used in, surface-enhanced Raman spectrometry sensors, colorimetric sensors, chemiluminescence sensors and fluorescence sensors because of their surface Plasmon resonance capabilities (37).

SALMONELLA ENTERITIDIS

One of the major health problem is food borne diseases that outcomes by eating the food that is polluted with different pathogens, however salmonella is the main reason behind the food borne disease among the humans as in 2011, in Europe about 95,548 cases stood conveyed for infections caused by salmonella (38).

Salmonella spp. is extensively diffused in the environment, but the bacteria's primary habitat is the intestinal system of animals (39). Salmonella infection is spread by eating infected foods such as milk, eggs, and chicken meat (40). Salmonella is found in 20% of global chicken products, and it can survive for a long period in animal and human body and facilitates biofilm development (41). Enteritidis and typhimurium serovar have been detected in the majority of salmonellosis outbreaks caused by chicken products intake (42). Enteritidis is the most common cause of salmonellosis in Europeans, accounting for 60% of cases. It is also the most common cause of salmonellosis worldwide (43).

BIOCIDAL ACTIVITY OF AgNPs AGAINST *SALMONELLA ENTERITIDIS*

Silver has been used as an antibacterial for centuries to combat illnesses and prevent spoiling, and it is well identified that ions of silver and Ag-based composites are extremely poisonous to Gram-positive and Gram-negative bacteria (44).

Because of improved sensitivity, resulting from the high surface/volume ratio, antimicrobial compositions in the shape of NPs could also be utilized as good biocidal tools (45). Ag in the form of AgNPs has been shown to have powerful biocidal effects on a variety of bacteria, including multidrug-resistant pathogens (45).

Free Ag^{+}, whether existent or discharged from nanoparticles, are thought to be able for binding with membrane of cell structures, weakening the membrane permeability and triggering the outflow of proton (46) despite the fact that AgNPs have been tried against the Salmonella genus (47).

Annually 320 tons of silver nanoparticles are being synthesized for bio sensing, imaging *etc.*, whereas AgNPs have great importance due to their antibacterial activity even when these are in solid state (48). The environmental changes have exceeded the number of MDR bacterial strains, so to overcome this issue scientists are synthesizing such drugs which will be working as bactericidal agents, these medications include Ag, AgNPs and some other metal salts (49).

AgNPs appear to propose an alternative to antibiotics in terms of antibacterial activity and the capacity to overcome antibiotic resistance in bacteria. As a result, AgNPs must be developed as antibacterial agents. Because of their huge surface-to-volume ratios and crystalline surface structure, AgNPs appear to be viable antibacterial agents among the many potential nanomaterials and antifungal, anti-inflammatory, and antiviral activities of AgNPs are also commonly used (50).

Because of their small size and wide surface area, AgNPs are well-known for having excellent antibacterial action against different pathogens such as bacteria, viruses, and fungus (51). Biosynthesized AgNPs were used to test the antimicrobial effect against salmonella *spp.* (52).

The use of silver metal as a germ-killing for wound soothing motivated investigators to investigate the character of AgNPs as antiseptic agents in contradiction of bacteria and viruses. Fungi and bacteria are two types of microorganisms. Ag NPs offer a lot of potential when it comes to fighting disease as bacteria and fungus that are multidrug resistant (53).

Because the antibacterial mechanism of Ag NPs differs for different species, susceptibility varies as well. Antimicrobial activity against methicillin-proof Gram-positive *Staphylococcus aureus* was found to be the most powerful. Methicillin-resistant Staphylococcus epidermidis was next, followed by methicillin-resistant Staphylococcus aureus. Streptococcus pyogenes, for example, Mild antimicrobials, on the other hand, Gram-negative bacteria were shown to be active i.e. Salmonella typhi (Salmonella typhi) and the bacteria Klebsiella pneumonia (54).

This could be owing to the cell wall of bacteria AgNPs being plasmolysed. Due to variations in the cell wall's construction and quantity of functional groups on the surface of different bacteria the Chitosan-

Ag colloid had better bactericidal efficiency against Escherichia coli while having relatively modest activity against Candida albicans (55). Due to their greater negative zeta potentials, oxidized pollutant mediated Ag NPs gain improved stability due to particle repulsion and display significant antibacterial action against Gram-positive bacteria (56).

The exact mechanism by which AgNPs act on microbes is unknown. Though, the mechanism is thought to be similar to that of Ag^{+}, and it encompasses linkage and devastation of the cellular walls, contact and interruption of biological molecules (enzymes, nucleic acid), and the formation of reactive oxygen species and free radicals that cause stress in cellular activities (57).

AgNPs work on biofilm and bacteria, successfully inhibiting biofilm formation and killing bacteria already present in biofilms. Ag NPs made from B. retusa and S. anacardium extracts had strong antibiofilm efficacy in contradiction of a variety of clinically pertinent human infections which were able to control the growth and structure of biofilms (58). This is due to Ag NPs biosorption into the biofilm matrix, which prevents cell-cell attachment (59). Due to changes in the makeup of the cell membrane, *Pseudomonas aeruginosa*, *E. coli*, *S. epidermidis*, and Gram-negative bacteria (*E. coli* and *P. aeruginosa*) are more vulnerable to NPs than Gram-positive bacteria (S. epidermidis) (60). Table I elaborates the minimum inhibitory concentration (MIC) where salmonella serovars were used and their susceptibility to antibiotics was considered as their minimum inhibitory concentration

Table I. *Salmonella* serovars used and their susceptibility to antibiotics, described as minimum inhibitory concentration (MIC mg/l)

Antibiotics	*S. enteritidis* MIC/mg/l	*S. hadar* MIC/mg/l	*S. senftenberg* MIC/mg/l	References
Sulfamethoxazole	64	>1.024	>1.024	(61)
Gentamicin	0.50	1	0.50	
Ciprofloxacin	0.015	0.5	0.25	
Ampicillin	0.5	>32	0.25	
Cefotaxime	0.06	0.12	0.12	
Ceftazidime	0.25	0.50	0.25	
Tetracycline	1	32	1	
Streptomycin	2	64	16	
Trimethoprim	0.50	0.50	0.50	
Chloramphenicol	4	8	8	
Colistin	2	2	2	
Florfenicol	4	4	8	
Kanamycin	4	4	4	
Nalidixic acid	4	>64	>64	

CONCLUSION

Bacteria have been evolving and become resistant to different antibiotics in this era of advancement. Though, it has caused complications to combat illness and to treat the infected ones. NPs are considered to show antimicrobial functions as an alternative to antibiotics which have the great power to overcome the rise of bacterial Multi-drug resistance. The study supports AgNPs to be used as a biocidal agent and more research is required to make the NPs more efficient for further usages.

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