



## Effect of metallic nanoparticles on microorganism: A review

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### Abstract

Nanotechnology has captured the attention of researchers in all basic sciences, including physics, chemistry, and biology. It is concerned with particle size range from 1-100 nanometers. In this review they give a brief description about Nanotechnology in Iraq, Types of synthesis, study the characterization and its application in various fields viz. medicine, industry, agriculture, electronic and in the oil field. Nanoparticles have been used in a variety of sectors of research and technology in recent years, ranging from material science to microbiology. As a result, nanoparticle synthesis can be considered an active area in nanoparticle research and application. Physical, chemical, and biological methods of nanoparticle synthesis are all available. The biological approach is the most effective of these.

**Keywords** Nanoparticles, Material science, Microbiology and Nanotechnology

### Introduction

In general, nanoparticles vary in source and proportions, such as organic or inorganic, natural or synthetic materials (Jumaah & Altaie, 2020). Nanoparticles are the fundamental principle of nanotechnology, and they have specific characteristics based on their scale, morphology, and other size-dependent properties (Khan et al., 2019).

Antibacterial properties are known to exist in some of these metal nanoparticles. The manufacture of such materials poses a challenge for both chemists and biologists in terms of selecting analytical methods that provide appropriate information about these materials (Sanches-lopez et al., 2020). The development of nanotechnology has enhanced the medical rules for preventing and identifying diseases, as well as cancer treatment (Jin et al., 2020). Chemical or biological processes could be used to manufacture nanoparticles. Chemical synthesis methods have been related to several adverse consequences, indicating the presence of toxic chemicals absorbed into the surface (Iravani et al., 2014; Ranjan et al., 2021). Biological nanoparticle synthesis methods based on microorganisms, enzymes, fungi, and algae are more ecologically responsible than chemical and physical methods (Shah et al., 2015).

A multitude of reaction factors, such as solvent, temperature, pressure, and pH, which can also be acidic, basic, or neutral, impact on biological green synthesis methodologies (Singh et al., 2015). Because of the availability of effective phytochemicals in various plant extracts, particularly leaves, such as ketones, aldehydes, flavones, amides, terpenoids, carboxylic acids, and ascorbic acids, In the synthesis of metal/metal oxide nanoparticles, plant biodiversity has received a lot of attention (Ammulu et al., 2021). This component is capable of transferring metal salts into metal nanoparticles (Makarov et al., 2014).

#### 1. Nanoparticle classification

The morphology, size, and shape of nanoparticles are used to divide them into different types. In this review, some of the most traditional clothing of nanoparticles are explained.

##### 1.1. Organic-based nanoparticles

Ferritin, micelles, dendrimers, and liposomes are among the organic nanoparticles. Organic nanoparticles are non-harmful to the environment, biodegradable, and some organic nanoparticles, like (liposomes and micelles) (Tiwari et al., 2008).

Because of these features, organic nanoparticles are an excellent alternative for drug delivery. The Nanosphere or Nano capsule is the known shape of (organic) or (polymeric) nanoparticles (Mansha et al., 2017). The matrix particles have a solid overall mass and adsorb other molecules on the spherical surface's outer side. Particles encapsulated the solid mass in the latter event (Rao & Geckeler., 2011).

## 1.2. Inorganic nanoparticles

Because inorganic nanoparticles do not contain carbon, they are not toxic. Inorganic NPs were biocompatible and hydrophilic, whereas organic nanoparticles were incredibly efficient metal oxide nanoparticles connected to the inorganic nanoparticle class.

### 1.2.1 Metal nanoparticle's

Metallic nanoparticles are generated from metals using destructive or constructive processes. Pure metal nanoparticles are synthesized using metal sources. Due to plasma resonance characteristics, metal nanoparticles have unique electrical characteristics. Shape, facets, and size all influence the synthesis of metal nanoparticles (Dreaden et al., 2012) metal NPs were included Aluminum, gold, silver, cadmium, iron, lead, cobalt, zinc, and copper. These have a small size (10–100 nanometer). Nanoparticles' surface properties include the area of the surface to volume ratio, surface charge, pore, size, area of the surface charge, structure, crystalline, amorphous, spherical, rod, hexagonal, crystalline (Salavati-Niasari et al., 2008).

### 1.2.2 Metal oxides nanoparticle's

Metal oxides were the most commonly used inorganic NPs, and they present a reasonable alternative to antibiotic resistance. They not only use processes of action that are completely different from those found in standard antibiotics, acting against bacteria that have already developed resistance, but they also target multiple biomolecules at the same time (Slavin et al., 2020). Numerous techniques could be used to characterize metal-based nanoparticles (Wang et al., 2017).

## 2. Properties of Nanoparticles

The physical and chemical properties of nanoparticles are the most common divisions. In this article, the properties of a few popular nanoparticles are presented.

### 2.1 Physical

Optical characteristics such as the nanoparticle's color, among physical properties, are UV absorption and reflection, as well as the light penetration, capabilities for reflection, and absorption in solution. It features mechanical characteristics like strength, ductility, tensile strength, as well as flexibility, which play an important role in their application. Magnetic and electrical characters of nanoparticles have their use in modern electronics as well as in renewable energy applications. Thermal conductivity is essential.

### 2.2 Chemical

Chemical structure nanoparticles with the target-like stability and sensitivity to components. The antibacterial, antifungal, disinfection and toxic properties of nanoparticles make them suitable for use in biomedical and environmental applications.

## 3 Characterization

The unique characteristics of a nanoparticle determine its potential and assignment. Various measuring techniques are used to quantify nanoparticles.

### 3.1 Size

One of the most essential and essential measures for nanoparticle classification is particle size. It determines the particle's size and distribution, as well as whether it is at the nano or micro scale. Electron microscopy is the most common technique for evaluating particle size and diffusion. Scanning Electron Microscope (SEM) and Transmission Electron Microscope (TEM) data are collected for this purpose. (Marsalek, 2014).

### 3.2 Surface area

In the determination of nanoparticles. The surface area is important, The volume ratio of a nanoparticle has a significant impact on performance and features. BET analysis was the most typical method for determining the surface. For calculating the surface area of a liquid, a simple titration was sufficient, but it is a simple method as a function of nuclear magnetic force (Sharma & Rao, 2014).

### 3.3- Composition

The chemical structure of nanoparticles influences their purity and performance. Increased concentrations of unnecessary elements in the nanoparticle can reduce its efficiency, resulting in secondary reactions and contamination in the process. In most cases, an X-ray photoelectron spectrophotometer was used to measure the composition (XPS). Aluminum, gold, iron, lead, silver, cobalt, zinc, cadmium, and copper are among 18 metal nanoparticles (Bzdek et al., 2016).

### 3.4 Surface morphology

The Surface morphology of nanoparticles plays an essential part in utilizing their features. Surface evaluation is frequently carried out using electron microscopy techniques like SEM and TEM (Hodoroaba et al., 2014).

### 3.5 Surface charge

The charge of a nanoparticle determines where interactions with the target zeta potentiometer were often used to determine surface charges and associated dispersion stability in a solution (Marsalek, 2014).

### 3.6 Crystalline

Crystalline was studied of the structure atoms and molecules in crystal solids, the structural configuration of nanoparticles was determined using X-ray, the electron or neutron diffraction process (Yano et al., 1996).

### 3.7 Concentration

The concentration of nanoparticles in the gaseous phase by the amount of air or gas needed, the amount of air or gas needed for the procedure is calculated. The concentration of nanoparticles of air or gas determines a system's performance or efficiency; a condensation particle counter is commonly used to determine levels (CPC).

## 4. Applications

Some of the most essential applications of nanoparticles are identified below.

### 4.1 Medicine

The application of nanoparticles in drug delivery has grown in popularity changed the medical field according to nanotechnology. nanoparticles can be used to deliver the antibiotic to the target place (Ganesh et al., 2013) by placing the drug in the desired area and the required dosage, overall drug consumption, and adverse effects are significantly reduced. Tissue engineering is a less expensive and less risky method of creating and replacing damaged tissue. It can be used to replace traditional treatments like artificial implants and organ transplants such as the synthesis of carbon nanotube scaffolds in bones (Mudshinge et al., 2011). Gold has long been used as surgical therapy and it is used in a variety of ways. The use of gold for memory enhancement is a common method of improving one's overall health (Shinde et al., 2012).

### 4.2 Food

Incorporating nanotechnology into the food industry, processing, protection, and packaging increases the quality of the product. In the case of food packaging, a Nanocomposite coating can directly deposit antimicrobial materials onto the coated film surface (Laad & Jatti, 2016).

### 4.3 Environmental remediation and renewable energy

Nanoparticle's distinct physical and chemical properties have elevated them to the forefront of waste management and performance enhancement in the renewable energy sector (Liu, 2006) soils contain nanoparticles and some of them have been shown to benefit the environment. The use of nanoparticles in environmental remediation also regarded as nano remediation has proven effective in reducing or removing contaminants from the environment (Nowack & Bucheli., 2007) nano remediation is one of the most practical treatments because it allows for in-situ treatment, reducing the need to pump groundwater out for treatment and excavate to create the largest possible site. Nanoparticles are injected into the groundwater stream to visually inspect the water while

transferring toxins (Liu, 2006) redox reactions are a common decontamination process. Surface water is disinfected, treated, and desalinated using nanoparticles. Heavy metals, microorganisms, and organic contaminants are all possible contaminants. It has been demonstrated to be effective in removing the need for chemicals that could result in secondary reaction products (Irvani, 2011).

## 5 Bio production of nanoparticles

For the production of nanoparticles, there are various techniques available, including chemical, physical, and biological methods (Cerjak, 2014). Chemical synthesis is useful since it yields large volumes of nanoparticles in a short amount of time. Further, the chemistry reagents most used for nanoparticle production and stabilization are harmful and cause impurities (Makarov et al., 2014). The demand for environmentally friendly, non-toxic nanoparticle production methods is generating interest in biological systems that avoid the use of harmful chemicals as byproducts. Plants, fungi, yeast, actinomycetes, bacteria, and other natural sources can all be used to make metal nanoparticles. Intracellular and extracellular substances can be produced by prokaryotic and eukaryotic organisms (Geonmonond et al., 2018).

### 5.1 Plants are used in the synthesis of nanoparticles

Plants are a better alternative for nanoparticle synthesis because the protocols used are free of harmful chemicals and natural capping agents are widely available, such as the production of gold and silver nanoparticles from geranium extract (Shahverdi et al., 2007). Aloe Vera plant extracts were also used to make gold Nano triangles and silver nanoparticles (Singaravelu et al., 2007) broths formed from boiling fresh plant leaves are used in most research on the creation of silver or gold nanoparticles, it was created use sun-dried *Cinnamomumcamphora* leaf extract on the other hand (Shankar et al., 2004; Lin et al.,) a simple green synthesis method for producing well-defined silver was recently reported (Vithiya & Sen, 2011) the method involves reducing silver nitrate at room temperature with the broth of the sun-dried Cassia fistula leaf without the use of additives.

### 5.2 Bacteria in the synthesis of nanoparticles

Bacteria have been examined the most for nanoparticle production due to their quick growth and the relative availability of genetic engineering. Pseudomonas, silver-producing bacteria isolated from silver mines, accumulated silver nanoparticles in the plasmas-space, but particles from 35 to 46 nanometer (Lovley et al., 1987). Milk-derived Lactobacillus strains were exposed to higher nanoparticle concentrations, resulting in morphologically distinct silver, gold, and alloy crystals (Shankar et al., 2003). Bacteria have also been used in the production of gold nanoparticles. pH plays an important role in regulating the shape and location of bacterial nanoparticles (Chandran et al., 2008). These nanoparticles have been detected and used in a range of applications, which include protein electrochemistry.

The most important application of bacteria would be the recovery of industrial silver (Huang et al., 2007).

### 5.3 The Use of Yeast in the Synthesis of Nanoparticles

When a silver-tolerant yeast species is challenged with soluble silver during the log stage of development, the bulk of the silver particles as elemental nanoparticles extracellularly. When challenged with soluble silver during the log development stage, metallic nanoparticles were collected from the medium via differential melting of the sample (Lin et al., 2010).

### 5.4 Fungi in Nanoparticle Synthesis

Because of their tolerance and bioaccumulation, fungi are taking center stage in studies of the biological creation of nanoparticles (Slawson et al., 1992) (e.g., use a thin solid substrate fermentation method). The fungus was the powerful credit request of extracellular enzymes, allowing for large-scale enzyme production. Significant benefits of using fungal.

### 5.5 Algae in the Synthesis of Nanoparticles

Though the principles of nanoparticle synthesis are similar in algae and yeast, only a few scientists have employed algae as a “Biofactory” for nanoparticle creation in comparison to other biosynthesis processes, marine algae biosynthesize highly stable extracellular gold nanoparticles in a short period of time. Palladium and platinum nanoparticles immediately begin with their corresponding nanoparticles.

### 5.6 Viruses in the Synthesis of Nanoparticle

The synthesis biological nanoparticle has already improved to include biological particles such as viruses, CCMV and CPMV virus were used to process inorganic materials. (Vithiya & Sen, 2011). TMV virus has successfully been found direct sulphide and crystalline mineralization and combinatorial screening discovered peptides capable of nucleating Nano crystal formation, which were then displayed on the surface of the bacteriophage (Singaravelu et al., 2007).

## 6. Synthesis of Metallic Nanoparticle

Metallic nanoparticles are synthesized in two ways: top-down and bottom-up. A bottom-up method is used (Rampino & Nord, 1941). Nano scale physical forces are used during self-assembly to connect units into large stable structures. (Bowman et al., 2008) ball milling and severe plastic deformation are two common examples top down and bottom-up, The top down method starts with a large-scale pattern and then reduces it to Nanoscale, making it quick to create but slow and unsuitable for large-scale production. Bottom-up approaches start with atoms or molecules and work up to Nanostructures, resulting in lower fabrication costs (Mallipeddi & Rohan, 2010).

## 7. Applications of Metallic Nanoparticles

### 7.1 Anti-Infective Agents:

AgNps surpasses chemically produced silver nanoparticles in terms of antiviral activity (Taylor et al., 2010). Metallic nanoparticles were described as HIV infection in one experiment (Lara et al., 2010). Silverworks as a veridical agent by binding to the glycoprotein gp120 in another few investigations (Baram-Pinto et al., 2009). This, in turn, decreases HIV1 infectivity by the ability to inhibit CD4-dependent virion binding (Papp et al., 2010) metallic nanoparticles have recently been described to be effective agents against many viruses (Sun et al., 2008).

### 7.2 Anti-Angiogenesis

Angiogenesis was a physiological process that is essential for embryonic development, tumor growth, organ growth, and repair, and wound healing. Some cancer cells may develop drug resistance, rendering the drugs released by the targeted nanoparticles ineffective. Furthermore, NPs may alter the stability, solubility, and pharmacokinetic properties of the drugs carried. Furthermore, some materials make use of

### 7.3 An anti-angiogenic agent

### 7.4 Tumour Therapy

According to the study, Au nanoparticles inhibited of heparin-binding proteins like (VEGF, BFGF, and VEGF) promoted angiogenesis in vivo (Tsai et al., 2007). Heparin binding proteins were absorbed into the surface of AuNPs and then denatured (Bhattacharya et al., 2004; Arvizo et al., 2011). AuNPs was investigated a VEGF adenoviral vector (Ramezani et al., 2008) mice treated with AuNPs had less edema a week after AdVEGF treatment than mice treated with the same medication. In vitro and in vivo, Eom and his team discovered that the 50nm AgNps has anti-tumor characteristics.

### 7.5 Multiple Myeloma

Nanoparticle-based treatments were found to be effective in mice with multiple myeloma, a type of cancer that affects the body's plasma cells. The gold nanoparticle inhibits the proliferation of multiple myeloma cells that are VEGF and BFGF dependent.

### 7.6 Leukemia

B-chronic Lymphocytic leukemia (CLL) is an unavoidable disease identified by apoptosis resistance. Co-culturing CCL B cells with the anti-VEGF antibody results in an increase in apoptosis. Gold nanoparticles are used in CLL therapy to improve treatment efficacy. Biocompatibility, the large specific surface area, function and characterization availability were all factors in the selection of gold nanoparticles. VEGF antibodies were coupled to the gold nanoparticles, and their efficacy in killing CLL B cells was studied.

## 7.7 Rheumatoid arthritis

Rheumatoid arthritis is autoimmune sickness in which the immune system functions and attack the joints of the afflicted, gold particles can infect on macrophage and prevent releasing inflammation without killing them, and can be transmitted to immune cells with low toxicity.

## 7.8 Photo thermal therapy

Gold NPs was absorbed a lot of light and efficiently convert photon energy to heat. Photo thermal therapy was an invasive therapy that converts photons to heat in cancer.

## 7.9 Radiotherapy

Gold-containing tumors absorb X-rays, as a result, more beam energy is imparted, resulting in an increase in local dose, especially in cancerous cells and it has grown strongly in the treatment of cancer.

## 7.10 Metallic nanoparticle as drug delivery

Delivery of drugs is a challenge because most chemotherapeutic drugs are distributed all over the world, resulting in toxicity and poor patient compliance. Metallic nanoparticles have been used in active and passive tumor cell browsing because their small size causes them to interact with bio molecules on the surface and inside cells, allowing for more precise therapeutic targeting. Precious metals include gold, nickel, silver, and iron (Díaz & Vivas, 2013; Doria et al., 2012). It utilizes non-toxic Au nanoparticles for tumor target (*in vivo*) that are biocompatible and displays surface optical Emission scattering (Qian et al., 2008).

However, using metallic nanoparticles used as drug delivery raises concerns since, while being inert and biocompatible, some percent of metallic particles can be preserved in the body after drug administration. These metallic nanoparticles can be easily conjugated with target specific cells (Sperling & Parak, 2010) as well as biocompatible polymers (polyethylene glycol) to extend their circulation for medicine and gene delivery applications (Ghosh et al., 2008; Nishiyama, 2007). It can also convert light to heat, allowing for the thermal ablation of cancer cells (Chen et al., 2010; Day et al., 2009). Paclitaxel, Cisplatin, and Oxiplatin (platinum-based therapies) have been delivered using Au nanoparticles as carriers. This study looked at how 2nm Au nanoparticles covalently bond to the therapeutic medication (Gibson et al., 2007). Gold sulphidene nano shells were produced as a photo-thermally regulated drug delivery device. These nano shells are encased in a nanofibrous substance (Gawande et al., 2016).

## 8 Metallic NPs as anti-microbial

### 8.1 Copper oxide Nanoparticles

The exact mechanism of copper nanoparticles' antimicrobial activities is unknown. It has the activity of the bacterium and antibacterial action (Lemire et al., 2013). The absorption of Cu ions and the increasing development of ROS have been linked

to the loss of bacterial cell viability. Surfaces of copper do not produce additional oxidative nucleic acid damage (Warnes et al., 2012). However, nucleic acids were released from damaged cells +that increases as the Cu content of the surface alloy decreases. According to them, Cu NPs are highly antimicrobial against *B. subtilis* and *B. anthrax* because their cell surfaces include more amines and carboxyl groups, and copper has a higher affinity for these groups.

### 8.2 Zinc oxide nanoparticles

Gram-positive and negative bacteria have been found to be extremely dangerous to ZnO nanoparticles (Ma et al., 2013; Chiriac et al., 2016). ZnO has a negligible influence on cells of human, for use as an antimicrobial activity (Espitia et al., 2012; Zhang et al., 2013). The activity of zinc oxide nanoparticles is proportional to particle size and concentration (Ma et al., 2013; Zhang et al., 2013). Among the processes responsible for ZnO nanoparticle antibacterial activity, the production of hydrogen peroxide at the surface is thought to be a more effective method of inhibiting bacterial growth. Hydrogen peroxide has an antagonistic effect on oxygen, because O<sub>2</sub> steal electrons from the cell walls of bacteria (microbial are negatively charged), so the structure of cell proteins, as well as the lipid on the membrane of cell, dissolves. Zinc oxides have been oxidized become damaged or even disintegrate completely (Ravishankar & Jamuna, 2011; Chiriac et al., 2016).

### 8-3-Titanium dioxide nanoparticles

Titanium oxide NPs have attracted a lot of attention. Nanoparticles have physical and chemical properties in these greatly influenced by the particle size and reveal quantum size effects (Othman et al., 2014). The use of nanometer-sized TiO<sub>2</sub> particles may improve TiO<sub>2</sub>'s antimicrobial activity even further (Othman et al., 2014).

### 8.4 Magnesium oxide nanoparticles

Magnesium is the fourth most abundant mineral in the human body, and it is the second most abundant intracellular agent after potassium. Material reacts with bacteria by causing reactive oxygen species (ROS) to be produced and affecting key microbial enzymes. Another important element in MgO nanoparticles' antibacterial action has been the alkaline effect (Tang & Lv, 2014). According to (Hossain et al., 2014) it can inactivate pathogens by creating ROS.

## 9 Metal nanoparticles' antifungal activity

Because of their properties, metal oxide nanoparticles (Au- Ag- Co- Cu) are also currently growing in popularity as a broad-spectrum antimicrobial treatment (Murphy et al., 2015) as well as the possibility of synthesizing microbial action (Elumalai & Velmurugan, 2015; Ravichandran et al., 2016). Other metallic nanoparticles have antimicrobial potential, including (Al – Fe- Mg- Ni-Pa- Pl and Ti). Because most experiments have focused on bacterial activity, there are only a few reports on the antibacterial mechanism of metal nanoparticles (Ravishankar & Jamuna., 2011; Warnes et al.,

2012; Chiriac et al., 2016). The role of these nanoparticles as antifungal agents were being debated at the moment. AgNPs have the ability to penetrate the fungal cell wall causing death.

They claimed nanoparticles can create silver ions, which result ROS, resulting in cell material (Kim et al., 2009; Kim et al., 2012; Kumar et al., 2014; Abkhoo & Panjehkeh, 2016). However, the primary mechanism of Ag ion and Ag NPs toxicity against *Saccharomyces cerevisiae* is neither oxidative stress nor membrane protein mobilization (Lipovsky et al., 2011) discovered that ZnO nanoparticles produce ROS, which significantly limits *Candida Albicans* production. The oxidative stress process caused by ROS formation, as well as any reaction of the fungal cell wall with ZnO NPs (Hameed et al., 2015). CuO nanoparticles were tested for bactericidal activities against *Eshirishea. coli*, *Staph. Aurous*, *A. Niger*, and *C. Albicans* (Katwal et al., 2015). AuNPs have previously been shown to have a dramatic reducing effect on *Candida* species H<sup>+</sup> efflux (Ahmad et al., 2013). This affects the reaction between gold nanoparticles and the ATP-driven enzyme (H<sup>+</sup>-ATPase), which inhibits proton pumping mediated by H<sup>+</sup>-ATPase.

This has an effect on the interaction between gold NPs and the ATP enzyme (H<sup>+</sup>-ATPase), which inhibits H<sup>+</sup>-ATPase-mediated proton pumping (Alghuthaymi et al., 2015). The particles can influence bacterial growth through a variety of mechanisms (Knetsch & Koole., 2011; Alghuthaymi, 2015; He et al., 2016). Metal nanoparticles were inhibited fungal growth in a variety of ways, including cell wall and membrane disruption, sporulation, spore inhibition and color changes in filamentous fungi colonies and yeast budding inhibition (Ogar et al., 2015; Hameed et al., 2015). It has been established that the accumulation of Mg-doped ZnO nanoparticles in *C. Albicans* membranes causes cell damage (Xia et al., 2016). Silver NPs caused Hyphae deformation and shrinkage, cellular damage resulting in cytoplasmic leakage, and organelle degeneration in fungal pathogen. Several factors can affect the mode of action and the effectiveness of nanoparticles (Kim et al., 2012; Hanus & Harris, 2013; Lee et al., 2013; Ogar et al., 2015). The size of the gold NPs had an effect on their antifungal activity, Because of the increased surface area, smaller particles had the greatest effect in this case. When zinc oxide NPs were combined with visible light illumination, the negative impact on the viability of the *Candida albicans* was amplified (Lipovsky et al., 2011).

The antimicrobial activity of biosynthesis Ag NPs was studied and it was discovered that bacteria has more sensitive to the nanoparticles than the fungus, certain biological mechanisms such as pigment and other substance production, metal, chelation, glutathione and oxalate secretion, may contribute to fungal tolerance (Rathnayake et al., 2012; Pócsi et al., 2011) droplets form in some fungi after treatment with silver NPs, implying could serve as a reservoir for water and metabolites necessary for growth of fungi (Ogar et al., 2015). Fungi's ability to produce organic acids may also result in the formation of metal-complexes as a protective mechanism (Suresh et al., 2016). Nickel oxide nanoparticles with antifungal activity after a function with 5-amino-2-

mercaptobenzimidazole, which increases particle dispersibility. Another option for developing the activity of nano particles was used nano fibers with antifungal functionality (Ifuku et al., 2015; Quiros et al., 2016; Tan et al., 2016). The presence of AgNPs on chitin nano fiber surfaces reduced the spore pathogenic fungi (Ifuku et al., 2015). Graphene has a layer of graphite with carbon atoms that properties make it appealing as a drug delivery system (Liu et al., 2013). It is possible to create Graphene oxide nanoparticles (Li et al., 2016; Pusty et al., 2016).

## 10. Metal nanoparticles as antiviral agents

Metal nanoparticles (NPs) use as anti-viruses for treatment of several diseases that kill millions of people, such as smallpox (Galdiero et al., 2011; Khandelwal et al., 2014). Silver and gold NPs have primarily antiviral activity to inhibit some viruses such as (HIV-1, hepatitis B, influenza and Tacaribe) viruses (Khandelwal et al., 2014). AgNPs smaller than 100 NM, have shown to be effective against hemorrhagic fever viruses. They have been investigated (Speshock & Hussain, 2009; Hussein-Al-Ali et al., 2014). As the nanoparticle's size decreases, it interacts with and inhibits viral molecules more.

## Conclusion

Several metal nano particles have antimicrobial effects against bacteria, fungi, and viruses, among other pathogens, It is effective in microbial diseases, Smaller particles make things easier for pathogenic bacterial species to enter target cells, as well as viruses and fungi, which are becoming increasingly popular due to their antimicrobial properties and their biological activities and one-of-a-kind properties. Metal NPs are valuable tools as broad-spectrum antimicrobials, important devices for controlling a variety of infections. There are worries concerning their discharge, as they can pose an environmental risk. Adventurous ways for the application of metal nano particles, such as the use of magnetic and coated nano particles that are effective antibacterial materials, preserving their antibacterial effectiveness while reducing the chances of contamination in the environment, used as an alternative to conventional therapy for combating pathogens.

## Conflict of Interest

The author hereby declares no conflict of interest.

## Consent for publication

The author declares that the work has consent for publication.

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## References

- Abkhoo, J., & Panjehkeh, N. (2017). Evaluation of antifungal activity of silver nanoparticles on *Fusarium oxysporum*. *International Journal of Infection*, 4(2).

- Ahmad, T., Wani, I. A., Lone, I. H., Ganguly, A., Manzoor, N., Ahmad, A., & Al-Shihri, A. S. (2013). Antifungal activity of gold nanoparticles prepared by solvothermal method. *Materials Research Bulletin*, 48(1), 12-20.
- Alghuthaymi, M. A., Almoammam, H., Rai, M., Said-Galiev, E., & Abd-Elsalam, K. A. (2015). Myconanoparticles: synthesis and their role in phytopathogens management. *Biotechnology & Biotechnological Equipment*, 29(2), 221-236.
- Ammulu, M. A., Viswanath, K. V., Giduturi, A. K., Vemuri, P. K., Mangamuri, U., & Poda, S. (2021). Phytoassisted synthesis of magnesium oxide nanoparticles from *Pterocarpus marsupium* root extract and its biomedical applications. *Journal of Genetic Engineering and Biotechnology*, 19(1), 1-18.
- Arvizo, R. R., Rana, S., Miranda, O. R., Bhattacharya, R., Rotello, V. M., & Mukherjee, P. (2011). Mechanism of anti-angiogenic property of gold nanoparticles: role of nanoparticle size and surface charge. *Nanomedicine: nanotechnology, biology and medicine*, 7(5), 580-587.
- Baram-Pinto, D., Shukla, S., Perkas, N., Gedanken, A., & Sarid, R. (2009). Inhibition of herpes simplex virus type 1 infection by silver nanoparticles capped with mercaptoethanesulfonate. *Bioconjugate chemistry*, 20(8), 1497-1502.
- Bhattacharya, R., Mukherjee, P., Xiong, Z., Atala, A., Soker, S., & Mukhopadhyay, D. (2004). Gold nanoparticles inhibit VEGF165-induced proliferation of HUVEC cells. *Nano Letters*, 4(12), 2479-2481.
- Bowman, M. C., Ballard, T. E., Ackerson, C. J., Feldheim, D. L., Margolis, D. M., & Melander, C. (2008). Inhibition of HIV fusion with multivalent gold nanoparticles. *Journal of the American Chemical Society*, 130(22), 6896-6897.
- Bzdek, B. R., Zordan, C. A., Luther III, G. W., & Johnston, M. V. (2011). Nanoparticle chemical composition during new particle formation. *Aerosol Science and Technology*, 45(8), 1041-1048.
- Cerjak, H. (2014). Book note: introductions to nanoparticles and nanomaterials.
- Chandran, S. P., Chaudhary, M., Pasricha, R., Ahmad, A., & Sastry, M. (2006). Synthesis of gold nanotriangles and silver nanoparticles using *Aloe vera* plant extract. *Biotechnology progress*, 22(2), 577-583.
- Chen, H., Shao, L., Ming, T., Sun, Z., Zhao, C., Yang, B., & Wang, J. (2010). Understanding the photothermal conversion efficiency of gold nanocrystals. *small*, 6(20), 2272-2280.
- Chiriac, V., Stratulat, D. N., Calin, G., Nichitus, S., Burlui, V., Stodoleanu, C., & Popa, I. M. (2016, June). Antimicrobial property of zinc based nanoparticles. In *IOP conference series: materials science and engineering* (Vol. 133, No. 1, p. 012055). IOP Publishing.
- Day, E. S., Morton, J. G., & West, J. L. (2009). Nanoparticles for thermal cancer therapy.
- Díaz, M. R., & Vivas-Mejía, P. E. (2013). Nanoparticles as drug delivery systems in cancer medicine: emphasis on RNAi-containing nanoliposomes. *Pharmaceuticals*, 6(11), 1361-1380.
- Doria, G., Conde, J., Veigas, B., Giestas, L., Almeida, C., Assunção, M., & Baptista, P. V. (2012). Noble metal nanoparticles for biosensing applications. *Sensors*, 12(2), 1657-1687.
- Dreaden, E. C., Alkilany, A. M., Huang, X., Murphy, C. J., & El-Sayed, M. A. (2012). The golden age: gold nanoparticles for biomedicine. *Chemical Society Reviews*, 41(7), 2740-2779.
- Du, L., Jiang, H., Liu, X., & Wang, E. (2007). Biosynthesis of gold nanoparticles assisted by *Escherichia coli* DH5 $\alpha$  and its application on direct electrochemistry of hemoglobin. *Electrochemistry Communications*, 9(5), 1165-1170.
- Elumalai, K., & Velmurugan, S. (2015). Green synthesis, characterization and antimicrobial activities of zinc oxide nanoparticles from the leaf extract of *Azadirachta indica* (L.). *Applied Surface Science*, 345, 329-336.
- Espitia, P. J. P., Soares, N. D. F. F., dos Reis Coimbra, J. S., de Andrade, N. J., Cruz, R. S., & Medeiros, E. A. A. (2012). Zinc oxide nanoparticles: synthesis, antimicrobial activity and food packaging applications. *Food and bioprocess technology*, 5(5), 1447-1464.
- Galdiero, S., Falanga, A., Vitiello, M., Cantisani, M., Marra, V., & Galdiero, M. (2011). Silver nanoparticles as potential antiviral agents. *Molecules*, 16(10), 8894-8918.
- Ganesh, K., & Archana, D. (2013). Review Article on Targeted Polymeric Nanoparticles: An Overview. *Am. J. Adv. Drug Deliv*, 3(3), 196-215.
- Gawande, M. B., Goswami, A., Felpin, F. X., Asefa, T., Huang, X., Silva, R., & Varma, R. S. (2016). Cu and Cu-based nanoparticles: synthesis and applications in catalysis. *Chemical reviews*, 116(6), 3722-3811.
- Geonmonond, R. S., Silva, A. G. D., & Camargo, P. H. (2018). Controlled synthesis of noble metal nanomaterials: motivation, principles, and opportunities in nanocatalysis. *Anais da Academia Brasileira de Ciências*, 90, 719-744.
- Ghosh, P., Han, G., De, M., Kim, C. K., & Rotello, V. M. (2008). Gold nanoparticles in delivery applications. *Advanced drug delivery reviews*, 60(11), 1307-1315.
- Gibson, J. D., Khanal, B. P., & Zubarev, E. R. (2007). Paclitaxel-functionalized gold nanoparticles. *Journal of the American Chemical Society*, 129(37), 11653-11661.
- Hameed, A. S. H., Karthikeyan, C., Kumar, V. S., Kumaresan, S., & Sasikumar, S. (2015). Effect of Mg<sup>2+</sup>, Ca<sup>2+</sup>, Sr<sup>2+</sup> and Ba<sup>2+</sup> metal ions on the antifungal activity of ZnO nanoparticles tested against *Candida albicans*. *Materials Science and Engineering: C*, 52, 171-177.
- Hanus, M. J., & Harris, A. T. (2013). Nanotechnology innovations for the construction industry. *Progress in materials science*, 58(7), 1056-1102.
- He, Y., Ingudam, S., Reed, S., Gehring, A., Strobaugh, T. P., & Irwin, P. (2016). Study on the mechanism of antibacterial action of magnesium oxide nanoparticles against foodborne pathogens. *Journal of nanobiotechnology*, 14(1), 1-9.
- Hodoroaba, V. D., Rades, S., & Unger, W. E. (2014). Inspection of morphology and elemental imaging of single nanoparticles by high-resolution SEM/EDX in transmission mode. *Surface and interface analysis*, 46(10-11), 945-948.
- Hossain, F., Perales-Perez, O. J., Hwang, S., & Román, F. (2014). Antimicrobial nanomaterials as water disinfectant: applications, limitations and future perspectives. *Science of the total environment*, 466, 1047-1059.
- Huang, J., Li, Q., Sun, D., Lu, Y., Su, Y., Yang, X., & Chen, C. (2007). Biosynthesis of silver and gold nanoparticles by novel sundried *Cinnamomum camphora* leaf. *Nanotechnology*, 18(10), 105104.
- Hussein-Al-Ali, S. H., El Zowalaty, M. E., Hussein, M. Z., Geilich, B. M., & Webster, T. J. (2014). Synthesis, characterization, and antimicrobial activity of an ampicillin-conjugated magnetic nanoantibiotic for medical applications. *International journal of nanomedicine*, 9, 3801.
- Ifuku, S., Tsukiyama, Y., Yukawa, T., Egusa, M., Kaminaka, H., Izawa, H., ... & Saimoto, H. (2015). Facile preparation of silver nanoparticles immobilized on chitin nanofiber surfaces to endow antifungal activities. *Carbohydrate polymers*, 117, 813-817.
- Iravani, S. (2011). Green synthesis of metal nanoparticles using plants. *Green Chemistry*, 13(10), 2638-2650.
- Iravani, S., Korbekandi, H., Mirmohammadi, S. V., & Zolfaghari, B. (2014). Synthesis of silver nanoparticles: chemical, physical and biological methods. *Research in pharmaceutical sciences*, 9(6), 385.
- Jin, C., Wang, K., Oppong-Gyebi, A., & Hu, J. (2020). Application of nanotechnology in cancer diagnosis and therapy-a mini-review. *International Journal of Medical Sciences*, 17(18), 2964.
- Jumaah, M. W., & Altaie, M. (2020, August). Application of Nanotechnology in Iraqi Construction Projects. In *IOP Conference Series: Materials Science and Engineering* (Vol. 901, No. 1, p. 012019). IOP Publishing.
- Käosaar, S., Kahru, A., Mantecca, P., & Kasemets, K. (2016). Profiling of the toxicity mechanisms of coated and uncoated silver nanoparticles to yeast *Saccharomyces cerevisiae* BY4741 using a set of its 9 single-gene deletion mutants defective in oxidative stress response, cell wall or membrane integrity and endocytosis. *Toxicology in Vitro*, 35, 149-162.
- Katwal, R., Kaur, H., Sharma, G., Naushad, M., & Pathania, D. (2015). Electrochemical synthesized copper oxide nanoparticles for enhanced photocatalytic and antimicrobial activity. *Journal of Industrial and Engineering Chemistry*, 31, 173-184.
- Khan, I., Saeed, K., & Khan, I. (2019). Nanoparticles: Properties, applications and toxicities. *Arabian journal of chemistry*, 12(7), 908-931.
- Khandelwal, N., Kaur, G., Kumar, N., & Tiwari, A. (2014). APPLICATION OF SILVER NANOPARTICLES IN VIRAL INHIBITION: A NEW HOPE FOR ANTIVIRALS. *Digest Journal of Nanomaterials & Biostructures (DJNB)*, 9(1).
- Kharissova, O. V., Dias, H. R., Kharisov, B. I., Pérez, B. O., & Pérez, V. M. J. (2013). The greener synthesis of nanoparticles. *Trends in biotechnology*, 31(4), 240-248.
- Kim, K. J., Sung, W. S., Suh, B. K., Moon, S. K., Choi, J. S., Kim, J. G., & Lee, D. G. (2009). Antifungal activity and mode of action of silver nanoparticles on *Candida albicans*. *Biomaterials*, 22(2), 235-242.
- Kim, S. W., Jung, J. H., Lamsal, K., Kim, Y. S., Min, J. S., & Lee, Y. S. (2012). Antifungal effects of silver nanoparticles (AgNPs) against various plant pathogenic fungi. *Mycobiology*, 40(1), 53-58.
- Knetsch, M. L., & Koole, L. H. (2011). New strategies in the development of antimicrobial coatings: the example of increasing usage of silver and silver nanoparticles. *Polymers*, 3(1), 340-366.

- Kumar, N., Palmer, G. R., Shah, V., & Walker, V. K. (2014). The effect of silver nanoparticles on seasonal change in arctic tundra bacterial and fungal assemblages. *PLoS One*, 9(6), e99953.
- Laad, M., & Jatti, V. K. S. (2018). Titanium oxide nanoparticles as additives in engine oil. *Journal of King Saud University-Engineering Sciences*, 30(2), 116-122.
- Lara, H. H., Ayala-Núñez, N. V., Ixtepan-Turrent, L., & Rodríguez-Padilla, C. (2010). Mode of antiviral action of silver nanoparticles against HIV-1. *Journal of nanobiotechnology*, 8(1), 1-10.
- Lee, K. J., Park, S. H., Govarthanan, M., Hwang, P. H., Seo, Y. S., Cho, M., ... & Oh, B. T. (2013). Synthesis of silver nanoparticles using cow milk and their antifungal activity against phytopathogens. *Materials Letters*, 105, 128-131.
- Lemire, J. A., Harrison, J. J., & Turner, R. J. (2013). Antimicrobial activity of metals: mechanisms, molecular targets and applications. *Nature Reviews Microbiology*, 11(6), 371-384.
- Li, C., Wang, X., Chen, F., Zhang, C., Zhi, X., Wang, K., & Cui, D. (2013). The antifungal activity of graphene oxide-silver nanocomposites. *Biomaterials*, 34(15), 3882-3890.
- Lin, L., Wang, W., Huang, J., Li, Q., Sun, D., Yang, X., & Wang, Y. (2010). Nature factory of silver nanowires: Plant-mediated synthesis using broth of *Cassia fistula* leaf. *Chemical Engineering Journal*, 162(2), 852-858.
- Lipovsky, A., Nitzan, Y., Gedanken, A., & Lubart, R. (2011). Antifungal activity of ZnO nanoparticles—the role of ROS mediated cell injury. *Nanotechnology*, 22(10), 105101.
- Liu, J., Cui, L., & Losic, D. (2013). Graphene and graphene oxide as new nanocarriers for drug delivery applications. *Acta Biomaterialia*, 9(12), 9243-9257.
- Liu, W. T. (2006). Nanoparticles and their biological and environmental applications. *Journal of bioscience and bioengineering*, 102(1), 1-7.
- Lovley, D. R., Stolz, J. F., Nord, G. L., & Phillips, E. J. (1987). Anaerobic production of magnetite by a dissimilatory iron-reducing microorganism. *Nature*, 330(6145), 252-254.
- Ma, H., Williams, P. L., & Diamond, S. A. (2013). Ecotoxicity of manufactured ZnO nanoparticles—a review. *Environmental Pollution*, 172, 76-85.
- Makarov, V. V., Love, A. J., Sinityna, O. V., Makarova, S. S., Yaminsky, I. V., Taliansky, M. E., & Kalinina, N. O. (2014). "Green" nanotechnologies: synthesis of metal nanoparticles using plants. *Acta Naturae (англоязычная версия)*, 6(1 (20)).
- Mallipeddi, R., & Rohan, L. C. (2010). Nanoparticle-based vaginal drug delivery systems for HIV prevention. *Expert opinion on drug delivery*, 7(1), 37-48.
- Mansha, M., Khan, I., Ullah, N., Qurashi, A., & Sohail, M. (2017). Visible-light driven photocatalytic oxygen evolution reaction from new poly(phenylenequinonylenes). *Dyes and Pigments*, 143, 95-102.
- Marsalek, R. (2014). Particle size and zeta potential of ZnO. *APCBEE procedia*, 9, 13-17.
- Mudshinge, S. R., Deore, A. B., Patil, S., & Bhalgat, C. M. (2011). Nanoparticles: emerging carriers for drug delivery. *Saudi pharmaceutical journal*, 19(3), 129-141.
- Murphy, M., Ting, K., Zhang, X., Soo, C., & Zheng, Z. (2015). Current development of silver nanoparticle preparation, investigation, and application in the field of medicine. *Journal of nanomaterials*, 2015.
- Nishiyama, N. (2007). Nanomedicine: nanocarriers shape up for long life. *Nature nanotechnology*, 2(4), 203.
- Nowack, B., & Bucheli, T. D. (2007). Occurrence, behavior and effects of nanoparticles in the environment. *Environmental pollution*, 150(1), 5-22.
- Ogar, A., Tylko, G., & Turnau, K. (2015). Antifungal properties of silver nanoparticles against indoor mould growth. *Science of the Total Environment*, 521, 305-314.
- Othman, S. H., Abd Salam, N. R., Zainal, N., KadirBasha, R., & Talib, R. A. (2014). Antimicrobial activity of TiO<sub>2</sub> nanoparticle-coated film for potential food packaging applications. *International Journal of Photoenergy*, 2014.
- Papp, I., Sieben, C., Ludwig, K., Roskamp, M., Böttcher, C., Schlecht, S., & Haag, R. (2010). Inhibition of influenza virus infection by multivalent sialic-acid-functionalized gold nanoparticles. *Small*, 6(24), 2900-2906.
- Pócsi, I. (2011). Toxic metal/metalloid tolerance in fungi—a biotechnology-oriented approach. In *Cellular effects of heavy metals* (pp. 31-58). Springer, Dordrecht.
- Pusty, M., Rana, A. K., Kumar, Y., Sathe, V., Sen, S., & Shirage, P. (2016). Synthesis of partially reduced graphene oxide/silver nanocomposite and its inhibitive action on pathogenic fungi grown under ambient conditions. *Chemistry Select*, 1(14), 4235-4245.
- Qian, X., Peng, X. H., Ansari, D. O., Yin-Goen, Q., Chen, G. Z., Shin, D. M., & Nie, S. (2008). In vivo tumor targeting and spectroscopic detection with surface-enhanced Raman nanoparticle tags. *Nature biotechnology*, 26(1), 83-90.
- Quirós, J., Gonzalo, S., Jalvo, B., Boltes, K., Perdigón-Melón, J. A., & Rosal, R. (2016). Electrospun cellulose acetate composites containing supported metal nanoparticles for antifungal membranes. *Science of the Total Environment*, 563, 912-920.
- Ramezani, N., Ehsanfar, Z., Shamsa, F., Amin, G., Shahverdi, H. R., Esfahani, H. R. M., & Shahverdi, A. R. (2008). Screening of medicinal plant methanol extracts for the synthesis of gold nanoparticles by their reducing potential. *Zeitschrift für Naturforschung B*, 63(7), 903-908.
- Rampino, L. D., & Nord, F. F. (1941). Preparation of palladium and platinum synthetic high polymer catalysts and the relationship between particle size and rate of hydrogenation. *Journal of the American Chemical Society*, 63(10), 2745-2749.
- Rao, J. P., & Geckeler, K. E. (2011). Polymer nanoparticles: preparation techniques and size-control parameters. *Progress in polymer science*, 36(7), 887-913.
- Rathnayake, W. G. I. U., Ismail, H., Baharin, A., Darsanasiri, A. G. N. D., & Rajapakse, S. (2012). Synthesis and characterization of nano silver based natural rubber latex foam for imparting antibacterial and anti-fungal properties. *Polymer Testing*, 31(5), 586-592.
- Ravichandran, V., Vasanthi, S., Shalini, S., Shah, S. A. A., & Harish, R. (2016). Green synthesis of silver nanoparticles using *Atrocarpusaltilis* leaf extract and the study of their antimicrobial and antioxidant activity. *Materials Letters*, 180, 264-267.
- RavishankarRai, V. (2011). Nanoparticles and their potential application as antimicrobials.
- Ranjan, A., Rajput, V. D., Minkina, T., Bauer, T., Chauhan, A., & Jindal, T. (2021). Nanoparticles Induced Stress and Toxicity in Plants. *Environmental Nanotechnology, Monitoring & Management*, 100457.
- Salavati-Niasari, M., Davar, F., & Mir, N. (2008). Synthesis and characterization of metallic copper nanoparticles via thermal decomposition. *Polyhedron*, 27(17), 3514-3518.
- Sánchez-López, E., Gomes, D., Esteruelas, G., Bonilla, L., Lopez-Machado, A. L., Galindo, R., & Souto, E. B. (2020). Metal-based nanoparticles as antimicrobial agents: an overview. *Nanomaterials*, 10(2), 292.
- Shah, M., Fawcett, D., Sharma, S., Tripathy, S. K., & Poinern, G. E. J. (2015). Green synthesis of metallic nanoparticles via biological entities. *Materials*, 8(11), 7278-7308.
- Shahverdi, A. R., Fakhimi, A., Shahverdi, H. R., & Minaian, S. (2007). Synthesis and effect of silver nanoparticles on the antibacterial activity of different antibiotics against *Staphylococcus aureus* and *Escherichia coli*. *Nanomedicine: Nanotechnology, Biology and Medicine*, 3(2), 168-171.
- Shankar, S. S., Ahmad, A., & Sastry, M. (2003). Geranium leaf assisted biosynthesis of silver nanoparticles. *Biotechnology progress*, 19(6), 1627-1631.
- Shankar, S. S., Rai, A., Ahmad, A., & Sastry, M. (2004). Rapid synthesis of Au, Ag, and bimetallic Au core-Ag shell nanoparticles using *Neem* (*Azadirachta indica*) leaf broth. *Journal of colloid and interface science*, 275(2), 496-502.
- Sharma, V., & Rao, L. J. M. (2014). An overview on chemical composition, bioactivity and processing of leaves of *Cinnamomum tamala*. *Critical reviews in food science and nutrition*, 54(4), 433-448.
- Shinde, N. C., Keskar, N. J., & Argade, P. D. (2012). Nanoparticles: Advances in drug delivery systems. *Res. J. Pharm. Biol. Chem. Sci*, 3, 922-929.
- Singaravelu, G., Arockiamary, J. S., Kumar, V. G., & Govindaraju, K. (2007). A novel extracellular synthesis of monodisperse gold nanoparticles using marine alga, *Sargassum wightii* Greville. *Colloids and surfaces B: Biointerfaces*, 57(1), 97-101.
- Singh, J., Dutta, T., Kim, K. H., Rawat, M., Samddar, P., & Kumar, P. (2018). "Green" synthesis of metals and their oxide nanoparticles: applications for environmental remediation. *Journal of nanobiotechnology*, 16(1), 1-24.
- Slavin, Y. N., Asnis, J., Häfeli, U. O., & Bach, H. (2017). Metal nanoparticles: understanding the mechanisms behind antibacterial activity. *Journal of nanobiotechnology*, 15(1), 1-20.
- Slawson, R. M., Van Dyke, M. I., Lee, H., & Trevors, J. T. (1992). Germanium and silver resistance, accumulation, and toxicity in microorganisms. *Plasmid*, 27(1), 72-79.
- Sperling, R. A., & Parak, W. J. (2010). Surface modification, functionalization and bioconjugation of colloidal inorganic nanoparticles. *Philosophical Transactions of the Royal Society A: Mathematical,*



- Physical and Engineering Sciences*, 368(1915), 1333-1383.
- Speshock, J., & Hussain, S. (2009). Novel nanotechnology-based antiviral agents: silver nanoparticle neutralization of hemorrhagic fever viruses. *Air Force Research Laboratory, Unclassified Document 88AWB-2009-4491*.
- Sun, L., Singh, A. K., Vig, K., Pillai, S. R., & Singh, S. R. (2008). Silver nanoparticles inhibit replication of respiratory syncytial virus. *Journal of Biomedical Nanotechnology*, 4(2), 149-158.
- Suresh, S., Karthikeyan, S., Saravanan, P., Jayamoorthy, K., & Dhanalekshmi, K. I. (2016). Comparison of antibacterial and antifungal activity of 5-amino-2-mercapto benzimidazole and functionalized Ag3O4 nanoparticles. *Karbala International Journal of Modern Science*, 2(2), 129-137.
- Tan, G., Sağlam, S., Emül, E., Erdönmez, D., & Sağlam, N. (2016). Synthesis and characterization of silver nanoparticles integrated in polyvinyl alcohol nanofibers for bionanotechnological applications. *Turkish Journal of Biology*, 40(3), 643-651.
- Tang, Z. X., & Lv, B. F. (2014). MgO nanoparticles as antibacterial agent: preparation and activity. *Brazilian Journal of Chemical Engineering*, 31, 591-601.
- Taylor, U., Klein, S., Petersen, S., Kues, W., Barcikowski, S., & Rath, D. (2010). Nonendosomal cellular uptake of ligand-free, positively charged gold nanoparticles. *Cytometry Part A: The Journal of the International Society for Advancement of Cytometry*, 77(5), 439-446.
- Tiwari, D. K., Behari, J., & Sen, P. (2008). Application of nanoparticles in waste water treatment 1.
- Tsai, C. Y., Shiau, A. L., Chen, S. Y., Chen, Y. H., Cheng, P. C., Chang, M. Y., & Wu, C. L. (2007). Amelioration of collagen-induced arthritis in rats by nanogold. *Arthritis & Rheumatism: Official Journal of the American College of Rheumatology*, 56(2), 544-554.
- Vithiya, K., & Sen, S. (2011). Biosynthesis of nanoparticles. *International Journal of Pharmaceutical Sciences and Research*, 2(11), 2781.
- Wang, L., Hu, C., & Shao, L. (2017). The antimicrobial activity of nanoparticles: present situation and prospects for the future. *International journal of nanomedicine*, 12, 1227.
- Warnes, S. L., Caves, V., & Keevil, C. W. (2012). Mechanism of copper surface toxicity in Escherichia coli O157: H7 and Salmonella involves immediate membrane depolarization followed by slower rate of DNA destruction which differs from that observed for Gram-positive bacteria. *Environmental microbiology*, 14(7), 1730-1743.
- Xia, Z. K., Ma, Q. H., Li, S. Y., Zhang, D. Q., Cong, L., Tian, Y. L., & Yang, R. Y. (2016). The antifungal effect of silver nanoparticles on Trichosporonasahii. *Journal of Microbiology, Immunology and Infection*, 49(2), 182-188.
- Yano, F., Hiraoka, A., Itoga, T., Kojima, H., Kanehori, K., & Mitsui, Y. (1996). Influence of ion-implantation on native oxidation of Si in a clean-room atmosphere. *Applied surface science*, 100, 138-142.
- Zhang, Y., R Nayak, T., Hong, H., & Cai, W. (2013). Biomedical applications of zinc oxide nanomaterials. *Current molecular medicine*, 13(10), 1633-1645.

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