Silver Nanoparticles; Synthesis Characterization Optical Properties and Therapeutic Applications

Rishi pal[1], Priyanka Jaiswal[2], Arman Dalal[3], Sandeep Rathor[4*], Vishal Garg[5], Bhupinder Bhyan[6], Omveer Singh[4*]

[1]Professor, Dept. of pharmaceutics, School of Medical & Allied Sciences, K.R.Mangalam University, Gurugram.
[2]Assistant Professor, Usha Martin University, Narayansoso village, Angara, Ranchi-835103 Jharkhand.
[3]Assistant Professor, Puran Murti College of Pharmacy, Kami Road, Sonipat - 131001, Haryana, India.
[4]MM College of Pharmacy, Maharishi Markandeshwar (Deemed to be university), Mullana-133207, Ambala, India.
[5]Professor, Jaipur School of Pharmacy, Maharaj Vinayak Global University, Dhand Tehsil Amer Jaipur Delhi NH 11 C, Jaipur, Rajasthan, 302020
[6]Associate Professor, Swift School of Pharmacy, Swift Group of Colleges, Punjab, India
Corresponding Author - Rishi pal:-Mail- rishi2105@gmail.com
Synthesis of Silver Nanoparticles, Synthesis Using Plant Media, Fungal-Derived Synthesis, Bacterial Triggered Synthesis.
***Co- Corresponding Author - Omveer Singh: -** Mail – omveerpharmd123@gmail.com
Therapeutic Applications, Wound healing, Anticancer Activity of AgNPs, AgNPs' anti-antigenic properties, AgNPs' anti-inflammatory properties, AgNPs' antiviral properties, Antifungal Activity of AgNPs, Antibacterial Potency of AgNPs, Cardiac implants, Silver nanoparticles' toxicity, Important Role in dentistry, Mechanism for Drug Delivery.
***Co- Corresponding Author – Sandeep Rathor: -** Mail **- rathor.s347@gmail.com**

Optical Properties, Characterisation techniques for nanoparticles, Methods for the production of silver nanoparticles**,** UV-Vis spectrophotometry, X-ray diffraction analysis (XRD), Fourier transform infrared spectroscopy (FTIR), Energy-dispersive X-ray spectroscopy (EDX), Scanning electron microscopy (SEM), Transmission electron microscopy (TEM), Dynamic light scattering (DLS), Ager electron spectroscopy, Low-energy ion scattering (LEIS).

Abstract: Silver nanoparticles with sizes between 1 and 100 nanometer are frequently used in industries such as catalysis, electronics, and photonics. They have special qualities like optical, electrical, and magnetic characteristics that can be used as antimicrobial, biosensor textile, cosmetics, composite fibres, and electronic components, as well as to extend the shelf life of food substances. The primary goal of this review was to concentrate on recent developments in silver nanoparticle formulation techniques as well as potential future applications. The potential for biological uses of silver nanoparticles is extremely significant.

A variety of physical, chemical, and biological methods have been used to create and stabilise silver nanoparticles. Many techniques, such as chemical simplicity with various organic and inorganic degrading agents, physicochemical reduction, electrochemical processes, and radiolysis, are used to create silver nanoparticles. The most often utilised component in all nanotechnology products is silver nanoparticles, according to manufacturers. To extend the shelf life, they can be added to food packaging polymers. The current review focuses on various synthesis methods and specifics of silver nanoparticles employed as drug delivery systems, antibacterial activity, toxicity, recent developments, and future considerations.

Keywords: Silver nanoparticles; physical methods; chemical methods, biosynthesis, antibacterial activities.

1. Introduction

A nanospeck is an extremely small object or speck that, in terms of the attributes it conveys, functions as a single unit. Nanomaterials' physical and chemical characteristics can differ from those of the same substance in the massive bulk class; nanosubatomic particles have one characteristic with a range of 1 to 100 nm. They are used in contact lenses, fabrics, cosmetics, water purifiers, computing equipment, wound dressing, advertising materials, nutrition handling, and surgical procedures. The single most widely recognised substance among manufacturers that can be employed in nanotechnology goods is silver nanoparticles. They can be included in food packaging polymers to lengthen food's shelf life [1]. As of now, silver nanoparticles (AgNPs) are the nanoparticles that are most frequently used. [1]. Silver nanoparticles (AgNPs) are now the most popular nanoparticles due to their extensive antibacterial activity. At least 383 of the 1628 items produced by nanotechnology contain silver nanoparticles [2]. Milk contains silver nanoparticles to decrease microbial multiplication [1]. When silver nanoparticles interact with bacteria, they cling to the cell wall and membrane, prevent cell multiplication, and ultimately cause cell death. The ionisation of silver during its dissolution in the cytosol produces nanoparticles that boost its bactericidal action. One of the key areas of modern science that enables researchers to develop outstanding nanoparticle (NP) size advances is nanotechnology. NPs are by definition particles with a diameter less than 100 nm. To create metal NPs with the smallest feasible size, various techniques are applied. [1]. Because to their unique features and use in numerous industries, Palladium, tin, copper, silver, and gold have all been used to make NPs, which has garnered considerable interest. It has been reported repeatedly throughout the years that NPs can be made utilising a number of synthetic techniques. Yet, the vast majority of the techniques offered are expensive and short-lived. A number of factors, including temperature, the dispersion agent used, and the surfactant, have a substantial long-term impact on the excellence and measure of the synthesised NPs. In order to create NPs with a certain form, extent, and enhanced properties, scientists are searching for a process that is both economically advantageous and environmentally friendly. Due to the negative consequences that various methods have on living organisms, scientists choose for biogenic alternatives for NP synthesis. [3, 47].

2. Silver nanoparticle synthesis and manufacturing: Ag nanoparticles are produced using a variety of techniques, including Syntheses involving matter, matter, and matter. Each technique has benefits and drawbacks, it's crucial to remember that. The organism reduces

Ag^+ to Ag^0 during the biological production of silver nanoparticles, acting as a capping, reducing, or stabilising agent. Due to their low cost, high yields, and low impact on the environment and human health, biological techniques based on natural chemicals obtained from plant and microbial sources have lately gained popularity. [9]. The numerous processes for producing silver nanoparticles are discussed in the sections that follow.

2.1. Chemical methods

Silver nanoparticles can be produced in a variety of methods. Chemical processes are favourable since they require equipment that is more useful and simple to use than biological approaches. Silver ions are known to take up electrons from the reducing agent and transform into the metallic state, which then comes together to form silver nanoparticles. Because of its affordability, $AgNO_3$ is one of the silver salts that is used most frequently in the chemical manufacture of silver nanoparticles [10,11]. In a 2002 report, Sun and Xia described how to make monodispersed silver nanocubes using nitrate reduction. [12]. Silver nanoparticles were produced by Mukherji and Agnihotri using $AgNO_3$ as a precursor, sodium borohydride, and trisodium citrate as stabilisers. Sodium borohydride is said to function well as a reductant to create silver nanoparticles with a size range of 5–20 nm. Trisodium citrate, on the other hand, works best as a reducing agent to produce silver nanoparticles that are between 60 and 100 nm in size. [13]. When used as a solvent and reducing agent alongside ethylene glycol, polyvinylpyrrolidone (PVP) has been found to produce silver nanoparticles with an average size of less than 10 nm. [14]. by employing polyvinyl alcohol as the solvent and hydrazine hydrate as the reducing agent. were able to demonstrate the production of silver nanoparticles. According to their research, the created nanoparticles had a spherical shape and were essential for biotechnology and medical research. [15]. the synthesised silver nanoparticles were also discovered to be spherical and to have different-sized spheres in an interesting study. [16].

Using the precursor heating technique, a silver nitrate solution is heated to the reaction temperature, and it is shown that the ramping rate has the biggest influence on the size of the nanoparticles. As opposed to the precursor injection technique, which involves injecting a silver nitrate aqueous solution, the reaction temperature is a key factor in particle size reduction and producing monodispersed.

Table 1: Silver nanoparticles that are monodispersed and almost spherical can be created chemically. [12]

Chemical Reducing Agents	Main Precursor	Experimental conditions
$Na_3C_6H_5O_7$ Trisodium Citrate used as a reducing agent.	$AgNo_3$	Diameter = (10-80) nm; temperature ≈ B.P
$C_6H_8O_6$ Ascorbic acid high reducing agent under chemical synthesis.	$AgNo_3$	Diameter = (16-26) nm Temperature = B.P
$C_3H_7No_2$ and sodium hydroxide used as a agent.	$AgNo_3$	Diameter = 9.9 nm; Temperature = 92 degree; time = 59 (minute)

C18H34O2 oleic acid also used as a reducing agent	AgNo3	Diameter ≈ (4-98 nanometer) ; temperature ≈ 110-160 degree; time = 16-120 minute
Sodium Citrate sometimes also called as trisodium citrate.	AgNo3	Diameter = (40-98) nm; temperature ≈ B.P ; pH ≈ 5.8-11.5

2.2 Physical methods

Evaporation-condensation and laser ablation are two physical techniques for producing silver nanoparticles. Limitations of these main technologies are the enormous consumption of energy and the lengthy time needed to complete the entire process.

According to Lee and Kang's research, heat breakdown of Ag+-oleate complexes produces monodispersed silver nanocrystallites [20]. A tiny ceramic heater was employed in a work by Jung et al. to create metal nanoparticles by evaporation/condensation processes. It was discovered that polydispersed nanoparticles were produced over time when the heater surface warmed to a steady temperature. These silver nanoparticles had a spherical shape and were not aggregated [21]. The polyol method has recently been shown to generate spherical nanoparticles of various sizes when subjected to laser ablation [17,22]. Ag these are silver nanoparticles were created by ablation with various lasers to explore the effects of laser wavelength on particle size, and it was found that a decrease in laser wavelength caused a decrease in particle diameter from 29 to 12 nm on average [23]. used different types of ablation like laser to create nanosized silver particles in water to assess the size and effectiveness of the production of colloidal particles made by femtosecond and nanosecond laser pulses The efficiency of femtosecond pulse production was significantly very poor as compared to nanosecond pulses. In addition, femtosecond laser pulses produced colloids that were smaller and less distributed than nanosecond laser pulses [24]. There are associates investigated the Glycerol directly metalized physically as a method of producing silver nanoparticles. The use of this strategy was shown to be a worthwhile substitute for laborious chemical methods. Consequential nanoparticles also possessed a tight size distribution and were not amenable to aggregation [25]. The benefits of physical production techniques include speed, the lack of harmful chemicals and the use of radiation as a reducing agent. Physical methods have drawbacks include solvent contamination, low yield, uneven dispersion, and excessive energy usage (Table 2) [26].

Table 2: Silver nanoparticles are made by physical and chemical processes.

Types	Biological characterization	Properties
Ammonium Chloride and Polymethacrylic acid used as a silver nanoparticles.	Physical and chemical method synthesis of silver nanoparticles Antimicrobial	Ultraviolet (UV- Visible), Reflectance spectrophotometry.

Synthesis of silver Nanoparticles by Physical method	Silver Nanoparticles Antibacterial properties.	EFTEM, Ultraviolet Characterisation.
Chitosan used as a reducing agent synthesis of silver nanoparticles.	Chitosan contains Antibacterial property	Differential Scanning Calorimetry, X- ray Diffraction Method
The biological characteristics of silver nanoparticles used as a Physical synthesis.	Biological activities of silver nanoparticles are Antibacterial Property.	DSC, Uv-Visible Spectroscopy.
Polyvinylpyrrolidone PVP used as a silver nanoparticle.	–	Infrared Spectroscopy, Differential scanning calorimetry.

2.3 Biological methods

It is expensive, time-consuming, and environmentally harmful to produce silver nanoparticles via physical and chemical methods. Therefore, it is crucial to create a process that is affordable and environmentally friendly, free of harmful substances [32] and other drawbacks of physical and chemical production methods. By controlling diverse biological activities, biological approaches close these gaps and have a variety of uses in the management of health. The employment of fungi, bacteria, and yeasts, in addition to plant sources, is one aspect of biological production systems. As a result of these sources, this method is widely used in nanoparticle-based medical applications. According to reports, microorganism- and plant-based nanoparticle production processes are less hazardous to the environment, safer, and more cost-effective than chemical synthesis [33, 34]. Plants and microbes can also take in and store environment from their inorganic metallic ions [35]. The use of microbes and plant sources is the primary method for producing silver nanoparticles biologically (Figure 1).

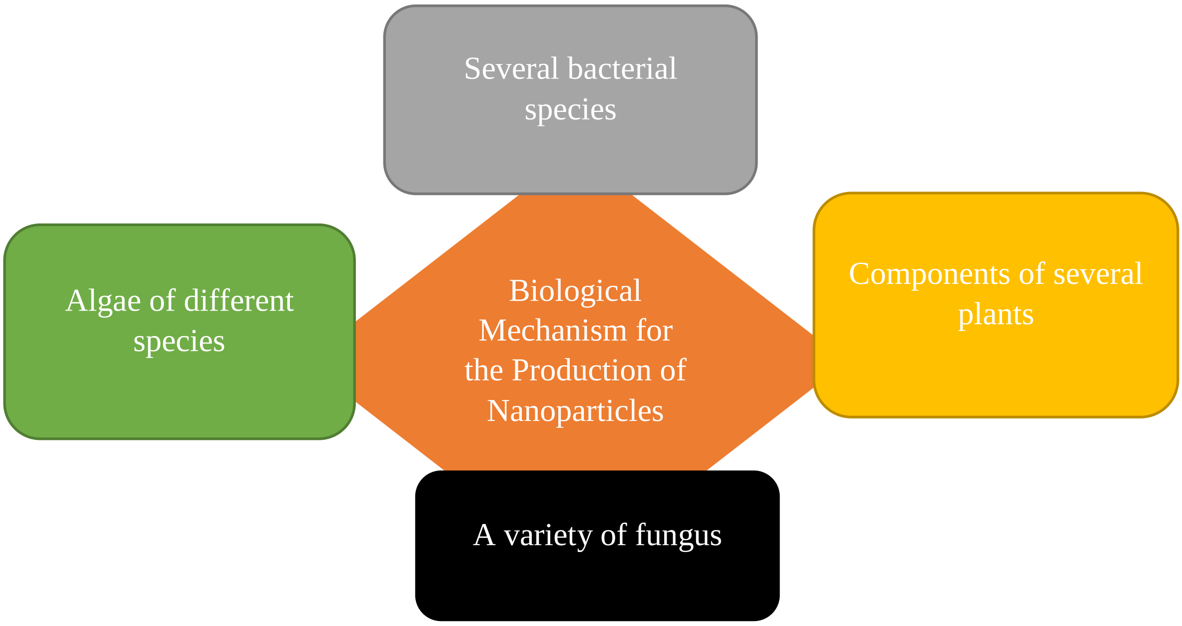


Fig.1. several biological processes are used to create silver nanoparticles.

Production in bacteria: Culture supernatant using the different bacteria of several bacteria, a study was recently conducted to create silver nanoparticles by reducing aqueous Ag+ ions. When silver ions interacted and the filtrate of cell, they produced silver the nanoparticles of Ag and the limited time is 5 minute, demonstrating the speed of this method. Piperitone was also found to partially impede silver conversion of nanoparticles to metallic Ag nanoparticles, according to this study [37]. It is significant to remember that Piperitone, a natural substance, inhibits the nitro reduction activity of Enterobacteriaceae. The bioreduction of silver ions to silver nanoparticles is thought to be somewhat hindered by certain Enterobacteriaceae strains, including Klebsiella pneumonia. Lactobacillus casei subspecies casei produces silver nanoparticles, which was confirmed by research by Korbekandi and colleagues.

Synthesis/production based on fungi: Silver nanoparticle synthesis has reportedly been facilitated by a variety of fungus [41]. Silver nanoparticles may be produced by fungi very quickly, it has been discovered. Several scientists have thoroughly investigated how fungus produces silver nanoparticles [32]. One study used Fusarium solani and silver nitrate to show how extracellular synthesis of spherical silver nanoparticles might occur [42]. Ag nanoparticles were biosynthesized by the Humicola sp., according to Syed and colleagues. Extracellular nanoparticles were demonstrated to be formed as a result of the reduction o by the interaction of Humicola sp., a precursor solution. With Ag+ ions. Silver nanoparticles are shaped during silver nitrate's bioreduction, which is mediated by the Pleurotus cornucopiae extract, according to Owaid and colleagues [40]. Arthroderma fulvum was used. in their experiments to biosynthesize silver nanoparticles with antifungal properties [22]. According to Vigneshwaran et al., Ag nanoparticles accumulated on the surface of Aspergillus flavus's cell wall as a result of the interaction between silver nitrate solution and the fungus.

Production in algae: Because it is affordable and environmentally safe, this technology can effectively replace physical and chemical ways of producing nanoparticles [15,16]. Algae are also highly capable of absorbing metals. Marine algae and other biological sources have been shown to have the ability to catalyse specific processes. Current and useful biosynthetic programmes require this skill [12, 19]. The reduction of silver ions to silver nanoparticles can be indicated by a colour change from yellow to brown, according to a study based on algal extract. The main deep Ag nanoparticles were also discovered by Rajeshkumar and colleagues at 32 hours, and it was shown that the length of incubation was closely related to the intensification of colour.

Production in yeast: It has been claimed that yeasts are capable of producing silver nanoparticles. Moreover, yeast-based silver nanoparticle production techniques are both economical and environmentally friendly. In this regard, a study based on Saccharomyces cerevisiae was carried out by Niknejad and colleagues. It was observed that after supplying the yeast culture with Ag+ ion, the washed-out taster gradually curved fuchsia-coffee with increasing incubation time. Moreover, a strong reddish-brown hue replaced the original hue of the solution. [25]. By interacting with soluble silver and a silver-tolerant yeast in its log phase of growth. showed in 2003 that extracellular creation of nanoparticles was possible.

Plant- or plant-extract-based synthetic methods: Plant-based production is preferable than chemical and physical processes because it saves money and the environment by avoiding the use of hazardous chemicals, high temperatures, and energy, much like other biological approaches [34, 39]. Several physiologically active chemicals can be found in aloe Vera leaves. A number of these components, including lignin, hemicellulose, and pectins, have been shown to be essential for the reduction of silver ions [18,26]. Silver nanoparticles were produced in an aqueous solution in a recent study using an extract of the Saudi Arabian shrub Origanum vulgare. As a result The reduction of Ag+ ions was proven to be the cause of the creation of silver nanoparticles,. Through this procedure, the reaction mixture's colour transitioned from light brown to dark brown. The same conditions, however, did not result in any colour change when the plant extract was absent.

3. NPs are categorised: There are three types of NPs: Organic nanoparticles and carbon based Nps.

3.1. NPs with an organic base

Inorganic NPs are those NPs that do not contain any carbon atoms, such as metal oxide and metal-based nanoparticles.

3.1.1. Metal NPs

Several metals are well-known for being recorded in this group, among them are lead, The elements cadmium (Cd), aluminium (Al), copper (Cu), cobalt (Co), gold (Au), iron (Fe), silver (Ag), and zinc (Zn) are all metals (Pb). They have special qualities based on their dimensions and features, such as increased surface area, pore size, the density of charge on the surface, spherical and cylindrical shape, colour, and amorphous and crystalline structures. In addition, NP characteristics are impacted by environmental elements such as air, heat, sunshine, and moisture (Table 3) [10, 44].

Table 3. Physio-chemical classification of metal nanoparticles

Types of Nanoparticles	Physico- Chemical Properties are Reported
Nanoparticle Zinc.	Antitumor, antimicrobial, antifungal, UV-Filtering.
Chemical properties of Nnaoparticles.	Highly reactive, high stability and more used.
Nanoparticle of Copper	Good thermal conductivity, High electrical, More movable and ductile and very high electrical activity.
Nanoparticle of ammonium	More sensitive to sunlight, Reactivity is highly, More heated Surface area is high
Cobalt or other copper Nanoparticles.	Toxic property, unstable and highly stability.

3.1.2. Metal Oxide NPs

Certain metals are prepared to produce oxides in an effort to improve their qualities because they have a higher propensity to do so (Table 4). Iron abruptly oxidises at ambient temperature in the presence of oxygen (O2) to generate iron oxide (Fe2O3) with better reactive characteristics than iron nanoparticles (Table 2). Metal oxide NPs have been developed and have improved properties, efficiency, and reactivity. Examples include titanic oxide (TiO2), silicon oxide (SiO2), zinc oxide (ZnO), magnetic iron ore (FeO4), iron oxide

(FeO3), aluminium oxide (Al2O3), and cerium oxide (CeO2). According to a survey of the literature, these NPs are more extraordinary than metal NPs. [11].

Table 4. Physiochemical characteristics and classification of metal oxide nanoparticles

Types of Nanoparticles	Physical and Chemical Properties are Reported
Aluminum oxide NP	Highly reactive, high sensitive, Moisture containing and less toxicity.
Nanoparticle containing Zinc oxide.	Antifungal Property, antibacterial and anticorrosive property are preesent .
Highly stable compound Silicon dioxide.	Highly stable, Less toxicity, Contain ability to functnalize
Heavy Metal Iron Nanoparticles.	Reactivity is low and Unstable.
Nanoparticles containing titanium oxide.	Contain High surface area and inhibits bacterial growth.

4. Review on Synthesis of Silver Nanoparticles

4.1. Physical Approach

By using a desiccation condensate process and applying atmospheric pressure to a vacuum tube shell, metal nanoparticles can be produced physically. Into the carrier gas is vaporised the source fabric, which is centred on a boat. Nanoparticles of many materials, including fullerene, Ag, Gold, and Pb, have already been created using vaporisation procedures [7-9]. AgNP produces tube furnaces, which have several drawbacks, but because tube ovens are larger and require more power to operate, the temperature of the environment is increased from about. The source material's attainment of thermal stability will take a lot of time. To maintain a constant operating temperature, a typical tube oven needs to be preheated for more than a few kilowatts and for at least a few ten minutes. Using a precise optical maser to remove metallic bulk components, silver nanoparticles were also produced [10–12]. With this method, pure colloids that will serve as the foundation for future applications can be produced [13]. In essence, the traditional physical synthesis of AgNPs uses the physical energies to produce AgNPs with proximally constrained size distribution. The best auxiliary approach for manufacturing AgNP powder is the physical methodology, which allows for relatively large volumes of AgNP sample in a single step. Yet it's important to consider the initial costs associated with purchasing equipment.

4.2. Photochemical Approach

There is also evidence for the synthetic strategy brought on by exposure. By employing light reduction in AgNO3, which acts as a stabilising agent to stop nanoparticles from assembling, Huang and colleagues produced AgNPs in multilayer synthetic clay suspensions. AgNP was decomposed into a single-mode with a brief lifespan after irradiation, which continued until the distribution's size and diameter were fairly constant [14]. This method is constrained by the requirement for expensive equipment and a laboratory setting.

4.3. Biological Approach

Recent research has focused on developing more practical and uncomplicated biosynthetic methods that utilise natural reducing components such polysaccharides, biological microbes, bacteria, and fungi, plant extraction, and green chemistry. Bacteria can produce inorganic chemicals either intracellularly or extracellularly. This enables the creation of biofabrics for nanoparticles like gold and silver. Because of its biotic properties, silver stands out in every way. Vilchis-Genus Nestor et al. used green tea extract as a stabilising agent to decrease gold-silver nanoparticles in an aqueous solution. [15]. because the organism used in this method is a non-pathogenic bacteria, the AgNPs produced are relatively stable and this process has other advantages. The biological technique offers numerous resources for producing silver nanoparticles and is seen as a method of nanoparticle synthesis that has advantages over conventional synthetic chemical routes, an environmentally friendly glide path, and an initial cost strategy. (2008) noted that Bacillus licheniform is grown in supernatant of the AgNP synthesis by lowering the aqueous Ag + ions [16].

4.4. Bacterial Triggered Synthesis

In addition to preventing the growth of biofilm, the lactobacillus fermentum prevents Pseudomonas aeruginosa from growing during the production of biogenic silver nanoparticles. Anisotropic nanoparticles of B. flexus were generated in the shapes of spherical (12 nm) and triangular (61 nm) particles [17]. It takes 3-5 days of ambient temperature incubation for AgNP to employ B. cereus [18]. Psychrophilic bacteria's cell-free culture supernatants were necessary for the formation and longevity of AgNP [19]. AgNPs with heterogeneous shapes of 15 nm (cube and hexagonal) are produced by Bacillus thuringiensis spore crystal fusion [20]. Escherichia coli, Klebsiella pneumonia, Plectonema boryanium UTEX 485, and aqueous $AgNO_3$ were utilised to produce the spherical silver nanoparticles, which precipitated after 28 days depending on the temperature, pH, and concentration of the reaction [21]. The silver ions only begin to rapidly drop within 5 minutes after the inclusion of the Entero bacteriaceae cell filtrate in the silver nitrate solution [22]. The interaction between silver ions and bacteria has an impact on the shape and size of the silver nanoparticles that are created by microorganisms [23, 24]. The best silver nanoparticles and unique morphology were found in the periplasm of Pseudomonas stutzeri AG259, which was successfully collected from silver mine [25]. Figure 1 presents the different uses for silver nanoparticles.

4.5. Fungal-Derived Synthesis

Helminthosporium tetramer cell-free filtration was used to create polydispersed spherical Agnips with dimensions between 17 and 33 nm, and these Agnips significantly inhibited bacterial growth [26]. According to certain reports, silver nanoparticles make Escherichia coli more susceptible than S. aureus [27]. Extracellular nanoparticles [28] were produced as a result of the thermophile Humicola sp fungus's response, which included Ag (+) ions that decreased the precursor solution. Optimal conditions, such as temperature 37°C, pH 6.0, and silver nitrate membrane concentration of 2.0 mm, were required for Aspergillus Niger to produce AgNPs [29]. However, one crucial effort involved the production of AgNP (5-50 nm) using wet biomass of Trichoderma reesei funguses at 28°C after 120 hours of continuous shaking. It was determined that the growth of fungus was greatly inhibited when silver nanoparticle concentrations between 30 and 200 mg/L were present. Moreover, silver nanoparticles with a strong antifungal activity were biosynthesized using strain GP-23 cell culture supernatant. Silver nanoparticles were produced using Trichoderma harzianum cell filtrate inside Three hours; investigation revealed ellipsoid & spherical Ag nanoparticles with an average size of 34.77 nm and a size range of 19-63 nm.

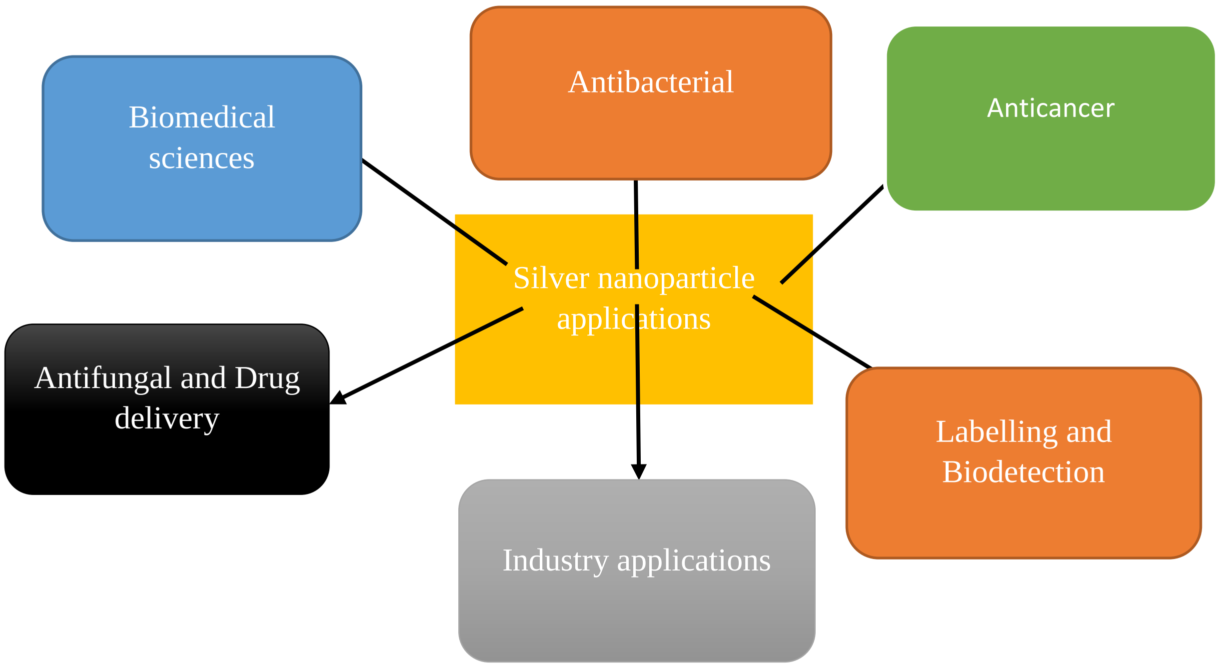


Fig: 1. Silver Nanoparticle Applications

When Aspergillus fumigates were exposed to the silver ion, an amazing synthesis of AgNPs with a dispersion of 525 nm was produced in a short period of time [38]. Fusarium oxysporum treatment uses agglomerated silver nanoparticles generated in a laboratory [39]. The common halogen tungsten lamp technology used by AgNP, however, was created in shorter time [40]. The enzyme on the surface of Verticillium is responsible for the breakdown of silver, and it was shown that the electric cell continued to grow even after AgNP was produced [41]. The biomimetic tube to plant mintage has been established using the microbial production of silver nanoparticles. Silver ions that make up silver nanoparticles undergo reduction due to the presence of enzymes in microorganisms [42]. Increased quantities of silver ions could be harmful to some species. As a result, using microorganism-produced nanosilver for biological purposes presents unique challenges [24].

4.6. Synthesis Using Plant Media

Citrus maxima (2.5-5.7 nm), Alternaria alternate (27-79 nm), Desmodium gangeticum (18-39 nm), Tectona grandis (30-40 nm), Syzygium cumini (10-15 nm), Rhynchotechum ellipticum (51-73 nm), and the latex of the genus Thevetia were among the plants whose compounds were extracted. [43]. An investigation employing antioxidants from blackberry, blueberry, and pomegranate as well as turmeric peels revealed that the size of silver nanoparticles created by using these extracts ranged between 20 and 500 nm, depending on their nature and the technique of synthesis [40]. It was demonstrated to be an effective catalyst for the reaction, causing AgNPs to develop rapidly in just 24 hours with a molecular size of 59 nm [41]. Using AgNPs produced with Delonix elata that had an 18 mV zeta potential after a 24-

hour confinement, the substance's stability is evaluated. Using the SILAR (successive ionic layer adsorption and reaction) technique, AgNP thin films with a significant volumetric area were produced using guava leaf extract. In this study, nanotriangles and hexagon-shaped AgNPs were made using the bacterium Potamogeton pectinatus L, and the polydispersed of the finished product was achieved by gradually increasing the amount of silver nitrate while using continuous magnification. Researchers have shown that polyphenol-rich foods are healthy [42]. Silver ions were transformed into silver nanoparticles (AgNPs) in natural sources by the presence of organics that were soluble in dihydrogen monoxide. In both the DPPH and the ABTS assays, AgNPs made from Prunus armeniaca (apricot) plant extracts were demonstrated to have a free radical scavenging activity of about 50%. Researchers identified 82.46 nm-sized needle-shaped AgNPs in a study employing the root extract of Coleus forskohli.

5. Biological Applications of AgNPs

AgNPs have been widely used in home appliances, food storage, healthcare sector, environmental, and biomedical applications because of their unique features. The current study includes a discussion of the biological characteristics of AgNPs, with a focus on their anti-inflammatory, anticancer, and anti-antigenic capabilities as well as their antibacterial potential against many kinds of microorganisms, including bacteria, fungi, and viruses.

5.1. Antibacterial Potency of AgNPs

By serving as an alternate antibacterial agent to antibiotics, AgNPs may be able to assist combat bacterial resistance to them in the age of antibiotic resistance. [16], AgNPs have been shown to have antibacterial activity against Escherichia coli, which results in cell death as a result of AgNP build-up in the cell wall. According to the study, the size and shape of AgNPs have a significant impact on their antibacterial activity [19]. In a different investigation, AgNPs made from various saccharides exhibited strong, broad-spectrum bactericidal efficacy against both Gram-positive and Gram-negative bacteria. The study's most notable finding was that the prepared AgNPs were effective against microorganisms with multiple resistances, including Staphylococcus aureus. AgNPs made by Cryphonectria species. Demonstrated strong antibacterial action against a variety of human pathogenic bacteria, as Salmonella typhi, E. coli, Candida albicans, and S. aureus. the AgNP-induced process of cell death.

5.2. Antifungal Activity of AgNPs

Those who have compromised immune systems frequently have fungal infections. It is challenging to treat all fungi infections due to the limited number of antifungal medications currently on the market. Development of biocompatible, non-toxic, and ecologically friendly antifungal drugs is therefore urgently needed. Numerous fungus species, including C. albicans, C. tropicalize, C. globate, C. krusei, C. parapsilosis, and T. mentagrophytes, have been found to be very sensitive to AgNPs' antifungal properties. According to the postulated mechanism of action, the cells are harmed as results of the disruption of the fungal envelop arrangement [24], [16] also shown AgNPs' notable antifungal efficacy. When coupled with fluconazole, biologically produced AgNPs have been shown to have significant antifungal activity against Candida albicans, Fusarium semitectum, Phoma lomerate, and several other types of fungi [24]. Similar to the previous study, it was discovered that AgNPs have antifungal action against Curvularia lunata, Macrophomina phaseolina, Rhizoctonia solani, Sclerotinia sclerotiorum, Alternaria alternate, and Sclerotinia sclerotiorum. [19]. the plant pathogenic fungus Fusarium oxysporum responded more favourably to the AgNPs generated by Bacillus species [18]. The antifungal activity of carbon nanoscrolls made of grapheme oxide and AgNPs against Candida albicans and Candida tropicalis has been demonstrated to be strong. In a different study, it was discovered that the green generation of AgNPs significantly reduced conidial germination and had a potent antifungal effect on Bipolaris sorokiniana [39]. Moreover, AgNPs suppressed the growth of Aspergillus fumigatus, Penicillium brevicompactum, Chaetomium globosum, Cladosporium cladosporoides, Mortierella alpina, and Stachybotrys chartarum. [19].

5.3. AgNPs' antiviral properties

The prevalence of viral infections is a widespread problem that is getting worse every day. Hence, the creation of antiviral medicines is a current necessity. Due to their antiviral activity and ability to stop viral development and survival, AgNPs can be extremely important [23, 26, 43]. According to a published study, AgNPs are highly effective at inhibiting the human immunodeficiency virus (HIV) and hepatitis B virus (HBV) [5, 19]. But the antiviral mechanism of AgNPs is still unidentified Using polyvinyl Pyrollidone-coated AgNPs that significantly reduced the transmission of both cell-free and cell-associated isolates of HIV-1, Lara et al. proposed the main mechanistic approach on anti-HIV activity involving viral replication taking place at an early stage. The capacity of AgNPs to reduce virus survival has been established in published studies, although the precise mechanism is yet unknown. Other reports indicate the use of AgNPs severely reduced the influenza virus' capacity to reproduce in Madin-Darby canine kidney cells (mammalian cell lines), and the viral titter in lung tissue was reduced. In the presence of green AgNPs, type 3 human parainfluenza virus developments was effectively inhibited .In another investigation, the 24 hours of application of AgNPs significantly reduced the virus concentration, infection prevalence, and severity of bean yellow mosaic virus disease.

5.4. AgNPs' anti-inflammatory properties

The immune system's activation results in elevated levels of pro-inflammatory cytokines, which our body needs to fight off foreign pathogens or particles. Chemotactic substances like interleukin-1 (IL-1), TNF, TGF, and complement factors are also released during immunological reactions, which also include these chemotactic substances. For that reason, we need enough anti-inflammatory chemicals and agents to control and end inflammation. AgNPs have served an important role as an anti-inflammatory agent among the many anti-inflammatory medications. Although AgNPs are regarded as a good antibacterial agent, they nonetheless have a rather modest anti-inflammatory effect. In rats given intracolonial (4 mg/kg) or oral (40 mg/kg) treatments with nanocrystallites silver, according to a study on the anti-inflammatory action of AgNPs, there is a significant decrease in colonic inflammation (NPI 32101). AgNPs have the ability to limit the anti-inflammatory actions early in the healing process, which can dramatically slow down the generation of inflammatory markers. The oedema and cytokine levels in paw tissues can be decreased by biologically produced AgNPs, which also suppress UV-B-induced cytokine production in HaCaT cells.

5.5. AgNPs' anti-antigenic properties

Angiogenesis that is harmful, along with specific types of malignancies, are the main causes of inflammatory and ischemic illnesses. The search for anti-antigenic compounds is underway in studies to improve treatment of angiogenic diseases. The demand for natural pro- and anti-angiogenic components that would contribute to an efficient physiological strategy for treating all types of antigenic illnesses remains despite the availability of numerous synthetic anti-angiogenic compounds. They may have anticancer and anti-angiogenic characteristics, according to recently published in vitro and in vivo research. Chan et al. suggested employing biologically produced AgNPs in the bovine retinal endothelial cells (BRECs) paradigm and shown considerable reduction of proliferation and migration in BRECs. According to their findings, AgNPs greatly suppressed BREC proliferation and migration following a 24-hour treatment period and demonstrated anti-angiogenic effects. An angiogenic process was introduced through the mechanism of vascular endothelial growth factor (VEGF) inhibition via activation of caspase-3 and DNA fragmentation. According to research, AgNPs severely inhibit the PI3K/Akt pathway that VEGF stimulates in BRECs.

5.6. Anticancer Activity of AgNPs

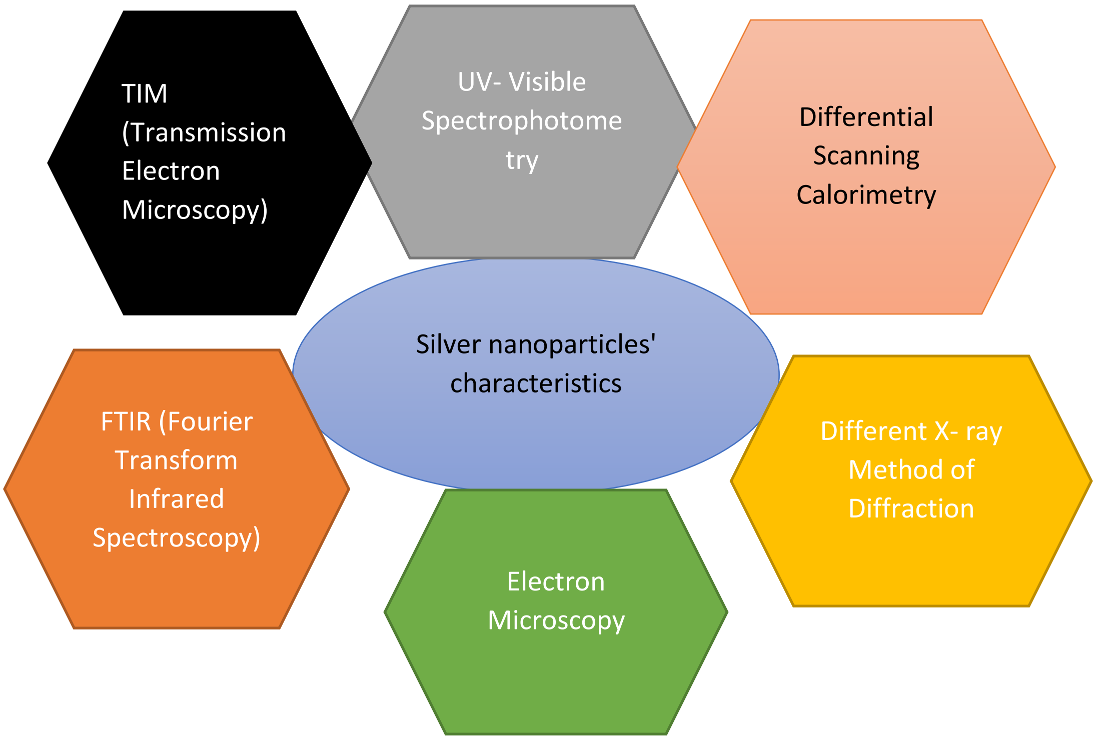
One in three people may contract cancer over their lifetime, making it a serious life-threatening condition. Although there are already a variety of chemotherapeutical drugs available for the treatment of various cancer types, these agents come with a number of side effects, and in particular, giving chemotherapeutic medicines intravenously is a subpar approach. In order to accurately target the intended cells or tissues, researchers must create nanomaterial that has no adverse consequences. In vivo and in vitro model systems both have advantages and shown anticancer activity, it has been revealed. In their investigation. Showed that the AgNP concentration determines whether cancer cells die or not.

6. Characterisation techniques for nanoparticles

The method of production of nanoparticles, characterisation is a crucial stage. Finding out a silver nanoparticle's shape, Area of surface and chemistry, and difference in wildlife is a crucial stage. Several methods are used to characterise silver nanoparticles (Figure 3).

- UV-Vis spectrophotometry
- X-ray diffraction analysis (XRD)
- Fourier transform infrared spectroscopy (FTIR)
- Energy-dispersive X-ray spectroscopy (EDX)
- Scanning electron microscopy (SEM)
- Transmission electron microscopy (TEM)
- Dynamic light scattering (DLS)
- Ager electron spectroscopy
- Low-energy ion scattering (LEIS)

Fig.3. Silver nanoparticles are characterised using a variety of approaches.



6.1. UV-Vis spectrophotometry

By tracking the stability and production of metallic nanoparticles, this technique is most frequently used to describe their properties. A distinctive peak with substantial absorptions in the visible region results from the creation of a metallic nanoparticle from its unique salt. Several investigations have shown that the absorption band at about 200-800 nm wavelength is best for the characterization of particles in the range of 2-100 nm. Among silver nanoparticles, the valence and conduction bands are incredibly near. Surface plasmon resonance absorption bands are created in these bands by the free movement of electrons. The chemical environment, the dielectric medium, and the silver nanoparticle size all affect how well they absorb. Many metal nanoparticles with a size range of 2-100 nm have been studied and examined for their surface plasmon peak. A surface plasmon resonance peak at the same wavelength was discovered using UV-Vis spectrophotometry, which was used to assess the stability of silver nanoparticles made through biological processes for nearly a year [18].

6.2. X-ray diffraction analysis (XRD)

An analytical method known as X-ray diffractogram analysis (XRD) is frequently available to study of metallic nanoparticles have this structure that are crystallised. The production of nanoparticles with crystalline structure is supported by the diffraction pattern that is produced.

The Debye-Scherrer equation is used making use of the XRD data to determine the particle size by calculating the width of the Bragg reflection law using the formula: d = K/cos, where d is the particle size (nm), K is the Scherrer constant, is the X-ray wavelength, is the full width half maximum, and is the diffraction angle. Thus, XRD can be used to analyse the structural characteristics of a variety of materials, including proteins, polymers, glasses, and superconductors. Furthermore, XRD is an effective technique for researching Nanomaterials.

6.3. Fourier transforms infrared spectroscopy (FTIR)

In addition to being used to analyse various capping agents, Fourier transformed infrared spectroscopy canister be used to investigate synthesised metal's surface chemistry nanoparticles and to see how biomolecules are involved in the creation of nanoparticles.

In FTIR, the sample is subjected to infrared radiation, part of which is absorbed by it and the rest of which passes through. The spectrums that are produced show the sample material's unique absorption and transmission. To ascertain the role of biological molecules in the reduction of silver nitrate to silver, FTIR is a practical, suitable, straightforward, and non-invasive method [18].

6.4. Energy-dispersive X-ray spectroscopy (EDX)

It has been established that the EDX technique may be used in nanotechnology to analyse the elemental makeup of a material. The elemental composition of each nanoparticle can be investigated using the distinct X-ray peaks that each element's atomic structure produces

6.5. Scanning electron microscopy (SEM)

SEM, which is also used to determine the size of various nanoparticles at the micro- (106) and Nano (109) scales, can be used to analyse the topography and morphology of nanoparticles. When a high-energy electron beam from a scanning electron microscope (SEM) is focused on the sample nanoparticles' surface, the backscattered electrons that result reveal the sample's distinctive characteristics. How cells are structured is compared previously & later Ag nanoparticle therapy using electron microscope analysis. The apparent changes in cell shape and the holes caused by in the cell have nanoparticles have reportedly been employed in several studies as markers of the antibacterial effect of nanoparticles. By using SEM, it was possible to compare the smooth and undamaged structures of control and silver nanoparticle-treated bacteria, as well as the damage done to the latter. The latter showed apparent morphological alterations to the cell membrane that resulted in a loss of membrane integrity.

6.6. Transmission electron microscopy (TEM)

The approach of expending transmission electron microscopy to characterise nanoparticles is particularly helpful since it may reveal details about their size and morphology. TEM photos provide more precise information about the The nanoparticles' dimensions, form, and crystallography because they have a higher than times in 1000 times advanced determination than SEM images.

6.7. Dynamic light scattering (DLS)

The measurement of molecule size and size distribution can be accomplished using the widely used DLS method. The size of nanoparticles has been measured using this technique, which is also frequently used to describe nanoparticles. Moreover, DLS has been widely used to characterise several types of nanoparticles, including magnetic nanoparticles, and has been shown to be effective at sizing them in the liquid phase. Due to the impact of Brownian motion, the DLS-determined nanoparticle size is typically bigger than TEM. By using this method, the typical size of nanoparticles in liquids can be ascertained [18, 48].

6.8. AES stands for Auger electron spectroscopy

AES is a top-notch analytical approach for nanotechnology since it is surface-sensitive and it results spread without aggregation, high surface area, and quantum confinement that are present at a sample's surface. AES can be used to determine the silver's oxidation state when it is a part of a hybrid compound.

Factors influencing the synthesis of silver nanoparticles

Physical and chemical parameters that govern the synthesis of silver nanoparticles have an impact on the shape, size, and morphology of nanoparticles. The following are the main elements that, in general, influence the creation of silver nanoparticles. :

- Production processes
- How much Temperature
- pH
- Time requires
- Size & Shape

Methods for the production of silver nanoparticles

Nanoparticles can be created using a variety of approaches, such as biological, chemical, and physical ones. These processes involve the creation of nanoparticles using a variety of organic or inorganic compounds as well as living things. It has already been said that green synthesis is more advantageous than other techniques because it is economical and environmentally benign. Moreover, high temperature, energy, and harmful chemicals are not used in green synthesis.

Temperature

A key element in the creation of nanoparticles has been discovered to be temperature. In the presence of a high temperature, spherical nanoparticles can be created. Nanotriangles formation, on the other hand, generally takes place at lower temperatures. A rise in temperature between 30 and 90 °C has been demonstrated to increase the frequency of synthesis and, occasionally, to promote the production of slighter nanoparticles Ag. Here are numerous publications that indicate room temperature, 25–37°C, is the ideal range for the biogenic creation of metal nanoparticles.

PH

In contrast to acidic media, most research indicate that basic media have better nanoparticle stability. Unstable agglomeration to several low ph (less than 11) was discovered to have several disadvantages of Ag nanoparticles. This leads to the conclusion that pH affects the size and shape of nanoparticles.

Time

Another aspect. A reduction is something that influences the reduction of ions to a bulk metal with distinct forms. In reaction time (minutes to hours). High absorbance peaks throughout the ideal time period show that the medium has higher concentrations of nanoparticles. The form, dimension, and ocular characteristics of Ag nanoparticles anisotropic method by different nanoparticles may be fine-tuned by changing temp, according to Rai and colleagues. The size of the nanoparticles, which might be spherical, triangular, hexagonal, or rectangular, was determined by the use of varied growing conditions.

Shape and size

Nanoparticles' properties are heavily influenced by their size, shape, and composition. The size and shape of the nanoparticle dictate its optimal activities, and the majority of its features are size-dependent.

Important Applications of silver nanoparticles in various industries

Due to their availability, inexpensive production, processing, and storage costs, antibacterial and optical qualities, availability, and a host of other characteristics, silver nanoparticles are sought after materials in a wide range of sectors In addition, due to their enormous surface area, spread without aggregation, high surface area, and quantum confinement, silver nanoparticles with a diameter of about 100 nm are crucial for large-scale businesses. These factors have led to the substitution of silver nanoparticles in the production of commodities and industries that are frequently used. Silver nanoparticles are currently being investigated in a number of industries, encompassing the fields of medical, biotechnology, material science, and energy. Studies are being done on the food and textile sectors, water disinfection systems, and medical items in particular (wound dressings, medicine delivery, biosensors, and orthopaedics). Silver nanoparticles are also used in some textile goods. (Table 5)

Using nanoparticles in agriculture helps to overcome the problems with food security brought on by climate change. A new dimension has been added to artificial implants, wound dressing, and the avoidance of post-operative microbial contamination in the field of medicine [19] thanks to the use of silver nanoparticles. [22]. In the textile, healthcare, and food industries, silver nanoparticles are very relevant as antibacterial agents. Silver nanoparticles, which function as an antimicrobial, have a wide range of uses, including the sterilisation of medical equipment, the treatment of water, and home appliances.

Table 5: Utilisation of silver nanoparticles in several industries

Main Application / Industry applications	Main Uses of silver Nanoparticles
Main uses of Pharmacological activity	Antibacterial Healing property present Antimicrobial
Under Textiles company	Ultraviolet ray blocking Textiles and medical devices
Potable water treatment	Water treatment Portable water Dysfunction of wastewater
Main applications of Biomedical different antiviral, antibacterial and antifungal activity.	Antitussive Anti-inflammation Antibacterial Antitumor Antiviral

7. Pharmacological applications or Uses of Silver Nnaoparticles

Wound healing: Inflammatory response, cell proliferation, synthesis of the components that make up the extracellular matrix and remodelling are some of the stages that the biochemical events in wound repair are divided into [15, 43]. Antibacterial drugs may be used alone or in conjunction with silver nanoparticles to enhance wound healing without infection. A fibroblast cell culture in vitro and partial thickness burns on patients have both been treated with dressings made of silver nanoparticles. The proliferation of fibroblasts and keratinocytes, which result in the restoration of normal skin, is not impacted by silver nanoparticle-based dressings, according to a study [16]. Furthermore, a combination of tetracycline and silver nanoparticles performs better than either antibiotic alone at reducing bacterial load while increasing macroscopic contraction of the wound than each antibiotic alone. Furthermore, these results point to the potential for treating infected skin wounds with a mixture of silver nanoparticles and antibacterial drugs.

The application of silver nanoparticles to the food sector

While silver nanoparticles are safe for humans and little amounts of them are excellent antimicrobials against viruses and bacteria. They can be used to sanitise food as a result. For example, Sunriver Industrial Co.'s nanosilver food bags, which are widely accessible, include silver nanoparticles.

Other applications in therapy

7.1. Antitumor activity

Cell signalling system changes are one of the many contributing factors to cancer. Killing cancer cells is an established method of cancer prevention using natural goods or medicinal plant active chemicals. In this regard, it is discovered that silver nanoparticles play a significant part in the suppression of cancer cells, and consequently, the formation and progression of the disease. Silver and gold nanoparticles have been shown to be essential in preventing the proliferation of cancer cells. Investigations into Ag nanoparticles the potential as an anticancer agent in vivo & in were conducted using lymphoma cell lines as a model. The study demonstrated that silver nanoparticles can kill lymphoma cells in vitro in a dose-dependent manner and suggested that these particles may possibly play a role in apoptosis induction. Furthermore, it was discovered that nanoparticles had a significant impact on the decrease in ascetic fluid volume in tumour-bearing animals [16, 45].

A human lung epithelial cell line was used to analyse the impact of silver nanoparticles on gene countenance. The research showed that exposure to silver nanoparticles affected the cell cycle and resulted in phase G2 or M phase are arrest. According to a recent study, silver nanoparticles activated the PtdIns3K signalling pathway to cause autophagy in cancer cells. Furthermore, wortmannin, an inhibitor of autophagy, meaningfully improved the anticancer based on research into human lung cancer, the action of silver nanoparticles in a melanoma cell model showed that there was a dose-dependent response. Ag nanoparticles made from Panax ginseng leaves were tested on human cancer cell lines for their cytotoxic and oxidative effects. The research showed that the nanoformulation was active against cancer. Khateef and associates investigated the cytotoxicity of different concentrations of silver nanoparticles. With higher silver nanoparticle absorptions, it was found that the suppression of cell growth was more pronounced. Also, the cell viability was reduced when silver nanoparticle concentration rose.

7.2. Mechanism for Drug Delivery

Approaches of delivering pharmaceutical or natural chemicals to achieve a desired potential therapeutic effect are referred to as drug delivery. It has been suggested that a number of formulations based on nanoparticles are crucial for therapeutic targeting against a variety of disorders. It has been claimed that polymers, such as microspheres and nanoparticles made of biodegradable substances, are utilised in cancer treatment and therapeutic targeting against disease processes including inflammation. Drug delivery methods for infectious and inflammatory illnesses are created using hybrid molecular units including silver nanoparticles. To achieve simultaneous intracellular administration of medications like doxorubicin and alendronate, Benyettou et al. created a drug-delivery system based on silver nanoparticles. It has been demonstrated that using this drug delivery technology improves both medications' anticancer therapeutic indices. According to a different study, Fe3O4 and silver nanoparticles can be combined to create highly effective magnetic hyperthermia mediators.

7.3. Important Role in dentistry

By killing or preventing the growth of microorganisms, silver nanoparticles have been found to have potential uses in dentistry. Silver nanoparticles have also been used in endodontic and dental prosthetics, among other things. The reported has been and tested & antibacterial function activity again bacterial strains in dental antibacterial to use Ag oxide made from Focus benghalensis root extract in possible applications. The study showed that a mixture of the extract and Ag2O the Ag particles exhibited potent antitumor properties. Silver nanoparticles killed Streptococcus mutans biofilms and prevented the formation of a clinical isolate planktonic Streptococcus mutans clinical isolate. established the bactericidal efficacy of Ag alongside. Hence, it is believed that silver nanoparticles have a significant the dental caries in the treatment.

7.4. Bone healing following orthopaedic implants

Silver nanoparticle-based implants are now favoured for orthopaedic implants due to a lower risk of infection. In order to lessen contagions linked to the main implants in orthopaedic, stainless steel is coated with silver nanoparticles. It has been determined through structural characterization that a special form of hydroxyapatite (HAp) coupled with silver nanoparticles is highly suited for orthopaedic implantation. According to a different study, HAp scaffolds with silver nanoparticle doping have a special antibacterial activity and can fend off bacterial infections brought on by bone implants. Produced a new, highly biocompatible Hap-built factual in an experimental investigation. They showed that nanocrystallites silver-doped HAp increased vitality and potentiated murine macrophage activation.

7.5. Cardiac implants

Cardiovascular implants can benefit from the antibacterial and anticoagulant capabilities of devices based on silver nanoparticles. In a recent study, the impact of silver nanoparticles on the left ventricle and perfusion pressure—two physiological markers of cardiovascular health—was examined. This study found that high blood pressure increased the danger of silver nanoparticles to the heart. Nano silver multilayer coatings with antibacterial and anticoagulant characteristics have been found by researchers. These multilayer coatings may present an excellent opportunity for medical device surface modification, particularly for cardiovascular implants. [10, 46].

8. Silver nanoparticles' toxicity

The usage of silver nanoparticles is expanding quickly on a global scale in various fields, including health. The possibility of silver nanoparticles having a negative impact on both human patients and the environment, nevertheless, must be kept to a minimum. In this regard, various research using different models in animal have been carried out to assess the nanoparticles of main toxicity of Ag nanoparticles and their impact on tissue architecture & function. The inner mitochondrial membrane becomes more permeable non-classically as a result of Ag^+. A higher degree of permeability was also present in the mitochondria of rat liver, which led to enlargement in the mitochondria, aberrant metabolism, and ultimately cellular demise. Glutathione levels were significantly depleted, mitochondrial membrane potential was lowered, and levels of reactive oxygen species were significantly increased, according to a subsequent investigation. These findings imply that oxidative stress is likely what facilitates Ag nanoparticles range of different sizes of 15 to 100 nm in liver cells' cytotoxicity. The appropriateness of evaluating nontoxicity was investigated using. The findings demonstrated that all studied particle types exhibited toxicity that varied with concentration, with silver nanoparticles being the most dangerous in this regard. Silver can be hazardous to fish embryos in both its liquid and particulate forms, according to research by Laban et al. from 2010 Sung et al. claim that continuous experience to Ag changed how the lungs functioned and led to other inflammatory reactions, like a reduction in tidal volume. According to silver nanoparticles of many extents, the minor Ag 11 nm nanoparticles caused the most vagaries, including cramming, lone of necrosis cell the liver focal necrosis, as well as cramming in the irritation. This demonstrates that the mice were poisoned more severely when exposed to the smaller particles.

Conclusion

Due to its numerous uses as antibacterial and antitumor agents as well as in food packaging, agriculture, and the healthcare industry, silver nanoparticles have a considerable impact on health management. Furthermore, it is common knowledge that the majority of empirical uses of antibiotics show resistance, which results in inefficiency. Hence, microorganisms that create biofilms are a major issue. Alternative therapeutic methods are receiving more attention globally as a means of addressing the issue of antibiotic resistance. Some potential alternatives to traditional methods include surface coatings or impregnations of Nanomaterials and silver nanoparticles as antibiofilm agents. The Ag nanoparticles of more over the most studied in the treatment of dental implants, wound healing and other therapies, and other therapies including regulating biological activities. Understanding of improved with different technology, a standardised infections will be made available by the use in medicine for the different novel particles in drug.

References

[1] Slawson RM, Trevors JT, Lee H. Silver accumulation and resistance in Pseudomonas stutzeri. Arch Microbiol. 1992;158:398–404. 10.1007/BF00276299. [CrossRef]Slawson RM,

Trevors JT, Lee H. Silver accumulation and resistance in Pseudomonas stutzeri . Arch Microbiol. 1992;158:398–404.

[2] Zhao G, Stevens SE. Multiple parameters for the comprehensive evaluation of the susceptibility of Escherichia coli to the silver ion. BioMetals. 1998;11:27–32. 10.1023/a:1009253223055. [PubMed] [CrossRef]Zhao G, Stevens SE. Multiple parameters for the comprehensive evaluation of the susceptibility of Escherichia coli to the silver ion. BioMetals. 1998;11:27–32.

[3] Hulkoti NI, Taranath TC. Influence of physico-chemical parameters on the fabrication of silver nanoparticles using Petrea volubilis L. stem broth and its anti-microbial efficacy. Int J Pharm Sci Drug Res. 2017;9:72–8. 10.25004/IJPSDR.2017.090206. [CrossRef]Hulkoti NI, Taranath TC. Influence of physico-chemical parameters on the fabrication of silver nanoparticles using Petrea volubilis L. stem broth and its anti-microbial efficacy. Int J Pharm Sci Drug Res. 2017;9:72–8.

[4] Durán N, Durán M, de Jesus MB, Seabra AB, Fávaro WJ, Nakazato G. Silver nanoparticles: a new view on mechanistic aspects on antimicrobial activity. Nanomed Nanotechnol Biol Med. 2016;12:789–99. 10.1016/j.nano.2015.11.016.

[5] Sohn EK, Johari SA, Kim TG, Kim JK, Kim E, Lee JH, et al. Aquatic toxicity comparison of silver nanoparticles and silver nanowires. BioMed Res Int. 2015;2015:893049. 10.1155/2015/893049. [PMC free article]

[6] Capek I. Preparation of metal nanoparticles in water-in-oil (w/o) microemulsions. Adv Colloid Interface Sci. 2004;110:49–74. 10.1016/j.cis.2004.02.003. [PubMed] [CrossRef]Capek I. Preparation of metal nanoparticles in water-in-oil (w/o) microemulsions. Adv Colloid Interface Sci. 2004;110:49–74.

[7] Hutchison JE, Greener. Nanoscience: a proactive approach to advancing applications and reducing implications of nanotechnology. ACS Nano. 2008;2:395–402. 10.1021/nn800131j. [PubMed] [CrossRef]Hutchison JE, Greener. Nanoscience: a proactive approach to advancing applications and reducing implications of nanotechnology. ACS Nano. 2008;2:395–402.

[8] Zewde B, Ambaye A, Stubbs Iii J, Raghavan D. A review of stabilized silver nanoparticles–synthesis, biological properties, characterization, and potential areas of applications. Nanomedicine. 2016;4(1043):1–4.Zewde B, Ambaye A, Stubbs Iii J, Raghavan D. A review of stabilized silver nanoparticles–synthesis, biological properties, characterization, and potential areas of applications. Nanomedicine. 2016;4(1043):1–4.

[9] Shanmuganathan R, Karuppusamy I, Saravanan M, Muthukumar H, Ponnuchamy K, Ramkumar VS, et al. Synthesis of silver nanoparticles and their biomedical applications – a comprehensive review. Curr Pharm Des. 2019;25:2650–60. 10.2174/1381612825666190708185506. [PubMed] [CrossRef]Shanmuganathan R, Karuppusamy I, Saravanan M, Muthukumar H, Ponnuchamy K, Ramkumar VS. et al. Synthesis of silver nanoparticles and their biomedical applications – a comprehensive review. Curr Pharm Des. 2019;25:2650–60.

[10] Ge L, Li Q, Wang M, Ouyang J, Li X, Xing MM. Nanosilver particles in medical applications: synthesis, performance, and toxicity. Int J Nanomed. 2014;9:2399–407. 10.2147/IJN.S55015. [PMC free article] [PubMed] [CrossRef]Ge L, Li Q, Wang M, Ouyang

J, Li X, Xing MM. Nanosilver particles in medical applications: synthesis, performance, and toxicity. Int J Nanomed. 2014;9:2399–407.

[11] Calderón-Jiménez B, Johnson ME, Montoro Bustos AR, Murphy KE, Winchester MR, Vega Baudrit JR. Silver nanoparticles: technological advances, societal impacts, and metrological challenges. Front Chem. 2017;5:6. 10.3389/fchem.2017.00006. [PMC free article] [PubMed] [CrossRef]Calderón-Jiménez B, Johnson ME, Montoro Bustos AR, Murphy KE, Winchester MR, Vega Baudrit JR. Silver nanoparticles: technological advances, societal impacts, and metrological challenges. Front Chem. 2017;5:6.

[12] Sun Y, Xia Y. Shape-controlled synthesis of gold and silver nanoparticles. Science. 2002;298:2176–9. 10.1126/science.1077229. [PubMed] [CrossRef]Sun Y, Xia Y. Shape-controlled synthesis of gold and silver nanoparticles. Science. 2002;298:2176–9.

[13] Agnihotri S, Mukherji S. Size-controlled silver nanoparticles synthesized over the range 5–100 nm using the same protocol and their antibacterial efficacy. RSC Adv. 2013;4:3974–83. 10.1039/C3RA44507K. [CrossRef]Agnihotri S, Mukherji S. Size-controlled silver nanoparticles synthesized over the range 5–100 nm using the same protocol and their antibacterial efficacy. RSC Adv. 2013;4:3974–83.

[14] Dang TMD, Le TTT, Fribourg-Blanc E, Dang MC. Influence of surfactant on the preparation of silver nanoparticles by polyol method. Adv Nat Sci Nanosci Nanotechnol. 2012;3:035004. 10.1088/2043-6262/3/3/035004. [CrossRef]Dang TMD, Le TTT, Fribourg-Blanc E, Dang MC. Influence of surfactant on the preparation of silver nanoparticles by polyol method. Adv Nat Sci Nanosci Nanotechnol. 2012;3:035004.

[15] Patil RS, Kokate MR, Jambhale CL, Pawar SM, Han SH, Kolekar SS. One-pot synthesis of PVA-capped silver nanoparticles their characterization and biomedical application. Adv Nat Sci Nanosci Nanotechnol. 2012;3:015013. 10.1088/2043-6262/3/1/015013.

[16] Amirjani A, Firouzi F, Haghshenas DF. Predicting the size of silver nanoparticles from their optical properties. Plasmonics. 2020;15:1077–82. 10.1007.

[17] Kim D, Jeong S, Moon J. Synthesis of silver nanoparticles using the polyol process and the influence of precursor injection. Nanotechnology. 2006;17:4019–24. 10.1088/0957-4484/17/16/004.

[18] Zhang X-F, Liu Z-G, Shen W, Gurunathan S. Silver nanoparticles: synthesis, characterization, properties, applications, and therapeutic approaches. Int J Mol Sci. 2016;17:1534. 10.3390/ijms17091534.

[19] Ganaie SU, Abbasi T, Abbasi SA. Green synthesis of silver nanoparticles using an otherwise worthless weed mimosa (Mimosa pudica): feasibility and process development toward shape/size control. Part Sci Technol. 2015;33:638–44. 10.1080/02726351.2015.1016644.

[20] Lee DK, Kang YS. Synthesis of silver nanocrystallites by a new thermal decomposition method and their characterization. ETRI J. 2004;26:252–6. 10.4218/etrij.04.0103.0061. [CrossRef]Lee DK, Kang YS. Synthesis of silver nanocrystallites by a new thermal decomposition method and their characterization. ETRI J. 2004;26:252–6. doi: 10.4218/etrij.04.0103.0061.

[21] Jung JH, Cheol OhH, Soo Noh H, Ji JH, Kim SS. Metal nanoparticle generation using a small ceramic heater with a local heating area. J Aerosol Sci. 2006;37:1662–70. 10.1016/j.jaerosci.2006.09.002. [CrossRef]Jung JH, Cheol OhH, Soo Noh H, Ji JH, Kim SS.

Metal nanoparticle generation using a small ceramic heater with a local heating area. J Aerosol Sci. 2006;37:1662–70.
[22] Torras M, Roig A. From silver plates to spherical nanoparticles: snapshots of microwave-assisted polyol synthesis. ACS Omega. 2020;5:5731–8. 10.1021/acsomega.9b03748. [PMC free article] [PubMed] [CrossRef]Torras M, Roig A. From silver plates to spherical nanoparticles: snapshots of microwave-assisted polyol synthesis. ACS Omega. 2020;5:5731–8. doi: 10.1021/acsomega.9b03748. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
[23] Tsuji T, Iryo K, Watanabe N, Tsuji M. Preparation of silver nanoparticles by laser ablation in solution: influence of laser wavelength on particle size. Appl Surf Sci. 2002;202:80–5. 10.1016/S0169-4332(02)00936-4. [CrossRef]Tsuji T, Iryo K, Watanabe N, Tsuji M. Preparation of silver nanoparticles by laser ablation in solution: influence of laser wavelength on particle size. Appl Surf Sci. 2002;202:80–5. doi: 10.1016/S0169-4332(02)00936-4. [CrossRef] [Google Scholar]
[24] Tsuji T, Kakita T, Tsuji M. Preparation of nano-size particles of silver with femtosecond laser ablation in water. Appl Surf Sci. 2003;206:314–20. 10.1016/S0169-4332(02)01230-8. [CrossRef]Tsuji T, Kakita T, Tsuji M. Preparation of nano-size particles of silver with femtosecond laser ablation in water. Appl Surf Sci. 2003;206:314–20
[25] Siegel J, Kvítek O, Ulbrich P, Kolská Z, Slepička P, Švorčík V. Progressive approach for metal nanoparticle synthesis. Mater Lett. 2012;89:47–50. 10.1016/j.matlet.2012.08.048. [CrossRef]Siegel J, Kvítek O, Ulbrich P, Kolská Z, Slepička P, Švorčík V. Progressive approach for metal nanoparticle synthesis. Mater Lett. 2012;89:47–50.
[26] Elsupikhe RF, Shameli K, Ahmad MB, Ibrahim NA, Zainudin N. Green sonochemical synthesis of silver nanoparticles at varying concentrations of κ-carrageenan. Nanoscale Res Lett. 2015;10:302. 10.1186/s11671-015-0916-1. [PMC free article] [PubMed] [CrossRef]Elsupikhe RF, Shameli K, Ahmad MB, Ibrahim NA, Zainudin N. Green sonochemical synthesis of silver nanoparticles at varying concentrations of κ-carrageenan. Nanoscale Res Lett. 2015;10:302. doi: 10.1186/s11671-015-0916-1. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
[27] Dubas ST, Kumlangdudsana P, Potiyaraj P. Layer-by-layer deposition of antimicrobial silver nanoparticles on textile fibers. Colloids Surf Physicochem Eng Asp. 2006;289:105–9. 10.1016/j.colsurfa.2006.04.012
[28] Pal S, Tak YK, Song JM. Does the antibacterial activity of silver nanoparticles depend on the shape of the nanoparticle? A study of the Gram-negative bacterium Escherichia coli. Appl Env Microbiol. 2007;73:1712–20. 10.1128/AEM.02218-06. [PMC free article]
[29] Ali W, Rajendran S, Joshi M. Synthesis and characterization of chitosan and silver loaded chitosan nanoparticles for bioactive polyester. Carbohydr Polym. 2011;83:438–46. 10.1016/j.carbpol.2010.08.004.
[30] Shrivastava S, Bera T, Roy A, Singh G, Ramachandrarao P, Dash D. Characterization of enhanced antibacterial effects of novel silver nanoparticles. Nanotechnology. 2007;18:225103. 10.1088/0957-4484/18/22/225103. [CrossRef]Shrivastava S, Bera T, Roy A, Singh G, Ramachandrarao P, Dash D. Characterization of enhanced antibacterial effects of novel silver nanoparticles. Nanotechnology. 2007;18:225103. doi: 10.1088/0957-4484/18/22/225103. [CrossRef] [Google Scholar]

[31] Tejamaya M, Römer I, Merrifield RC, Lead JR. Stability of citrate, PVP, and PEG coated silver nanoparticles in ecotoxicology media. Env Sci Technol. 2012;46:7011–7. 10.1021/es2038596.
[32] Iravani S. Bacteria in nanoparticle synthesis: current status and future prospects. Int Scholar Res Not. 2014;2014:359316. 10.1155/2014/359316. [PMC free article] [PubMed] [CrossRef]Iravani S. Bacteria in nanoparticle synthesis: current status and future prospects. Int Scholar Res Not. 2014;2014:359316. doi: 10.1155/2014/359316. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
[33] Makarov VV, Love AJ, Sinitsyna OV, Makarova SS, Yaminsky IV, Taliansky ME, et al. “Green” nanotechnologies: synthesis of metal nanoparticles using plants. Acta Nat. 2014;6(20):35–44. 10.32607/20758251-2014-6-1-35-44. [PMC free article]
[34] Gowramma B, Keerthi U, Rafi M, Rao DM. Biogenic silver nanoparticles production and characterization from native stain of Corynebacterium species and its antimicrobial activity. 3 Biotech. 2015;5:195–201. 10.1007/s13205-014-0210-4. [PMC free article]
[35] Shah M, Fawcett D, Sharma S, Tripathy SK, Poinern GEJ. Green synthesis of metallic nanoparticles via biological entities. Materials. 2015;8:7278–308. 10.3390/ma8115377. [PMC free article] [PubMed]
[36] Ahmad S, Munir S, Zeb N, Ullah A, Khan B, Ali J, et al. Green nanotechnology: a review on green synthesis of silver nanoparticles – an ecofriendly approach. Int J Nanomed. 2019;14:5087–107. 10.2147/IJN.S200254. [PMC free article] [PubMed
[37] Shahverdi AR, Minaeian S, Shahverdi HR, Jamalifar H, Nohi A-A. Rapid synthesis of silver nanoparticles using culture supernatants of Enterobacteria: a novel biological approach. Process Biochem. 2007;42:919–23. 10.1016/j.procbio.2007.02.005.
[38] Korbekandi H, Iravani S, Abbasi S. Optimization of biological synthesis of silver nanoparticles using Lactobacillus casei subsp. casei. J Chem Technol Biotechnol. 2012;87:932–7. 10.1002/jctb.3702.
[39] Liu Y, Fu J, Chen P, Yu X, Yang P. Studies on biosorption of Au3+ by Bacillus megaterium. Wei Sheng Wu Xue Bao. 2000;40:425–9. [PubMed]Liu Y, Fu J, Chen P, Yu X, Yang P. Studies on biosorption of Au3+ by Bacillus megaterium . Wei Sheng Wu Xue Bao. 2000;40:425–9.
[40] Das VL, Thomas R, Varghese RT, Soniya EV, Mathew J, Radhakrishnan EK. Extracellular synthesis of silver nanoparticles by the Bacillus strain CS 11 isolated from industrialized area. 3 Biotech. 2014;4:121–6. 10.1007/s13205-013-0130-8. [PMC free article] [PubMed] [CrossRef]Das VL, Thomas R, Varghese RT, Soniya EV, Mathew J, Radhakrishnan EK. Extracellular synthesis of silver nanoparticles by the Bacillus strain CS 11 isolated from industrialized area. 3 Biotech. 2014;4:121–6
[41] Guilger-Casagrande M, de Lima R. Synthesis of silver nanoparticles mediated by fungi: a review. Front Bioeng Biotechnol. 2019;7:287. 10.3389/fbioe.2019.00287. [PMC free article] [PubMed] [CrossRef]Guilger-Casagrande M, de Lima R. Synthesis of silver nanoparticles mediated by fungi: a review. Front Bioeng Biotechnol. 2019;7:287.
[42] Ingle A, Rai M, Gade A, Bawaskar M. Fusarium solani: a novel biological agent for the extracellular synthesis of silver nanoparticles. J Nanopart Res. 2008; 11:2079. 10.1007/s11051-008-9573-y.

[43] Nisha , Omveer Singh , Sandeep Rathor , Sadia Parveen , Soma Ghosh , Shailesh Sharma , Hina Sharma , Nitish Gaur. (2023). Desloratadine: An Insight on Acute Inflammation. Journal of Pharmaceutical Negative Results, 590–598. https://doi.org/10.47750/pnr.2023.14.02.73

[44] Manohar Chouhan , Sandeep Rathor , Vishal Garg , Ambika Sharma , Pritam Singh , Jay Chandra , Vikram Kumar , Sanavi Byahut , Omveer Singh. (2023). Enhancement Of Solubility And Dissolution Characteristics Of Etoricoxib By Solid Dispersion Technique Using Different Grade Of Peg Carrier Using. Journal of Pharmaceutical Negative Results, 3233–3242. https://doi.org/10.47750/pnr.2023.14.02.380

[45] Mahbubur Rahman, Yashika, Manveen Kaur, Anurag, Omveer Singh, A REVIEW ON PSORIASIS, NeuroQuantology, Volume 20, No 16 (2022), 10.48047/NQ.2022.20.16.NQ880588

[46] Rathor S, Bhatt DC, Aamir S, Singh SK, Kumar V. A comprehensive review on role of nanoparticles in therapeutic delivery of medicine. Pharmaceutical nanotechnology. 2017 Dec 1;5(4):263-75.

[47] Rathor S, Bhatt DC. Formulation, Characterization, and Pharmacokinetic Evaluation of Novel Glipizide- phospholipid Nano-complexes with Improved Solubility and Bio-availability. Pharmaceutical Nanotechnology. 2022 Apr 1;10(2):125-36.

[48] Kumar V, Rathor S. Overactive Bladder (OAB) Management: An Overview and Scope of Nano Drug Carriers. Nanoscience & Nanotechnology-Asia. 2021 Dec 1;11(6):20-8.

Dr. OMVEER SINGH

B PHARM, PHARM D (DOCTOR OF PHARMACY) (P.B.)

Department of Pharmacy Practice, **Maharishi Markandeshwar (Deemed to be University), Ambala -Yamunanagar Highway, Mullana - Ambala, 133-207 (Haryana)**. He Has Been Completed B Pharm from Nims University Jaipur Rajasthan and Pharm D (Pb) From Nims University, Jaipur, Rajasthan. And, He Had More Than 4 Years of Teaching Experience as an Assistant Professor in Department of Pharmacy Practice. He Had 6 Months of Experience As A Director In Lifecare Pvt. Ltd. Company. He Had Done Pharm D. Project on the Topic of ―The Assessment of Stress & Obesity As Risk Factors For Cardiovascular Diseases In The Cardiology Department of A Tertiary Care Teaching Hospital.‖ ; A Prospective Study**.** He Is Actively Involved In Research.

He has published 6 patents in Indian patent window. He has published more than 23 high quality papers in international and national journals of repute; with high citation score. He Has Attended More Than 250 Conferences at National and International Level. He is author of 4 books, ―PHARMACY PRACTICE‖, ―PHARMACOTHERAPEUTICS, PHARMACEUTICAL CHEMISTRY‖ and ―PHYSICAL PHARMACEUTICS‖ in the Different-Different Publications as per the syllabus prescribed by the Pharmacy Council of India.

Dr. Sandeep Rathor working as an Assistant Professor at M.M. College of Pharmacy, Maharishi Markandeshwar (Deemed to be University) Mullana-133207, Ambala, Haryana (INDIA) (Accredited by NAAC with Grade 'A++'). Dr. Sandeep Rathor has his graduation B.Pharmacy from the Postgraduate Institute of Medical Sciences (PGIMS Medical College),
PT.B.D. Sharma University of Health Sciences, Rohtak (Haryana) in the year 2013 and post-graduation M.Pharmacy in pharmaceutics from Postgraduate Institute Medical Sciences (PGIMS Medical College), PT.B.D. Sharma University of Health Sciences, Rohtak (Haryana) in the year 2015. Ph.D. under the guidance of Prof. D.C. Bhatt from Guru Jambheshwar University of Science and Technology, Hisar (Haryana). He has qualified GPAT entrance examination four Times (2013, 2014, 2015, and 2016). He has a total of 7 years of Experience in Teaching and Research. He also provides GPAT Coaching to Students at GPAT Adda Pharma Academy. He has 13 publications, 1 Book chapter, and 1 Patent to his credit. Attended 8 international conferences, 32 National Conferences, and 8 Workshops.