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Nanoparticlesas Microbial Inhibitors

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A detailed overview of the synthesis, properties and applications of nanoparticles (NPs) in various forms is given in this analysis. NPs are small materials in the range of 1 to 100 nm in size. Based on their properties, shapes or proportions, they can be divided into various groups. Fullerenes, metal NPs, ceramic NPs, and polymeric NPs are among the various classes. Due to their high surface area and nanoscale dimensions, NPs possess unique physical and chemical properties. It is stated that their optical properties depend on the scale, which imparts different colors due to absorption in the visible field. They also rely on their unique size, shape and structure for their reactivity, durability and other properties. They are ideal candidates for different commercial and domestic applications due to these characteristics, including catalysis, imaging, medical applications, energy-based science, and environmental applications.Lead, mercury and tin heavy metal NPs are stated to be so rigid and stable that their deterioration is not readily attainable, which may contribute to many environmental toxicities.

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I. INTRODUCTION:

Since the last century, nanotechnology has been a well-known research field. Since Nobel laureate Richard P. Feynman introduced " nanotechnology " during his well-known 1959 lecture, " There is plenty of room at the bottom " (Feynman, 1960), numerous groundbreaking advances in the field of nanotechnology have been made (Khan, Saeed, & Khan, 2019). At the nanoscale stage, nanotechnology has developed materials of different types. Nanoparticles (NPs) are a large class of materials containing particulate matter with a minimum dimension of less than 100 nm (Laurent *et al*., 2010).Depending on the overall shape these materials can be 0D, 1D, 2D or 3D (Tiwari *et al.,* 2012). The significance of these materials was recognized when researchers discovered that size would affect a substance's physiochemical properties, such as optical properties. NPs of 20 nm gold (Au), platinum (Pt), silver (Ag) and palladium (Pd) have distinctive colors of wine red, yellowish green, black and dark black, respectively (Khan, Saeed, & Khan, 2019).We provide a general overview of the various forms, methods of synthesis, characterizations, properties and applications of NPs in this review article. Future elements and suggestions are also given in the last section.

II. WHAT IS NANO PARTICLE:

Nanotechnology has gained huge attention over time (Ealias & Saravanakumar , 2017). Nanoparticles are the basic component of nanotechnology. Nanoparticles are particles between 1 and 100 nanometres in size and are made up of carbon, metal, metal oxides or organic matter (Hasan S 2015; Ealias & Saravanakumar , 2017). Compared to their respective particles at higher scales, the nanoparticles exhibit distinctive physical, chemical and biological properties at the nanoscale. This is due to the volume of a comparatively larger surface region, increased reactivity or stability in a chemical phase, increased mechanical strength, etc (Ealias&Saravanakumar , 2017). These properties of nanoparticles have led to different applications being used. The nanoparticles differ from various dimensions, to shapes and sizes apart from their material (Cho *et al.* 2013). A nanoparticle can be either a null dimension where the length, width and height are set at a single point, such as nano dots, one dimension where it can only have one parameter, such as graphene, two dimensions where it has length and width, such as carbon nanotubes, or three dimensions where it has all the parameters, such as length, width and height, such as gold nanoparticles (Ealias & Saravanakumar , 2017).The shape, size and composition of the nanoparticles are different. It is circular, cylindrical, tubular, conical, hollow, spiral, smooth, etc. or uneven and ranges in size from 1 nm to 100 nm (Ealias&Saravanakumar , 2017). With surface changes, the surface may be consistent or irregular. Any nanoparticles of either loose or agglomerated single or multi crystal solids are crystalline or amorphous (Machado *et al*. 2015) (Ealias&Saravanakumar , 2017). Numerous methods of synthesis are either being produced or enhanced to improve the properties and reduce the cost of production. Some methods are modified to achieve process specific nanoparticles to increase their optical, mechanical, physical and chemical properties (Cho *et al.* 2013). A vast development in the instrumentation has led to an improved nanoparticle characterisation and subsequent application (Ealias & Saravanakumar , 2017).

Nanoparticles are materials in which the basic unit falls within the nanometer scale range (1-100 nm) in three-dimensional space, or where at least one dimension is within this range (Laurent *et al*.). Nanomaterials have shown broad spectrum antimicrobial activity against Gram positive and Gram negative bacteria, mycobacteria and fungi (Wang *et al.* 2017). The antibacterial activity of nanoparticles varies among the different types of nanoparticles. Although it is not well understood that nanoparticles have specific antibacterial activity, it is suggested that multiple mechanisms can contribute to antimicrobial mechanisms. The physical structure of the nanoparticle itself may have inherent antibacterial properties due to its membrane damaging abrasiveness, as seen in Graphene oxide nanoparticles (Fernando, Gunasekara, & Holton, 2018).

III. DIFFERENT TYPES OF NANO PARTICLES

In general, nanoparticles are categorized as organic, inorganic, and carbon-based.

A. Organic nanoparticles

Organic nanoparticles or polymers are generally considered to be dendrimers, micelles, liposomes and ferritin, etc. These nanoparticles are biodegradable, non-toxic, and some particles have a hollow heart, often known as nanocapsules, such as micelles and liposomes (Figure1), and are sensitive to thermal and electromagnetic radiation such as heat and light (Tiwari *et al*. 2008) (Ealias & Saravanakumar , 2017). These specific features make them an excellent option for the distribution of medicines. In addition to their usual characteristics such as size, composition, surface morphology, etc., the drug carrying power, its stability and delivery mechanisms, either the trapped drug or the adsorbed drug system determine their field of application and their performance (Ealias & Saravanakumar , 2017). In the biomedical area, for example, organic nanoparticles are most frequently used in the drug delivery system, since they are powerful and can also be inserted into specific parts of the body, also known as targeted drug delivery (Ealias & Saravanakumar , 2017)

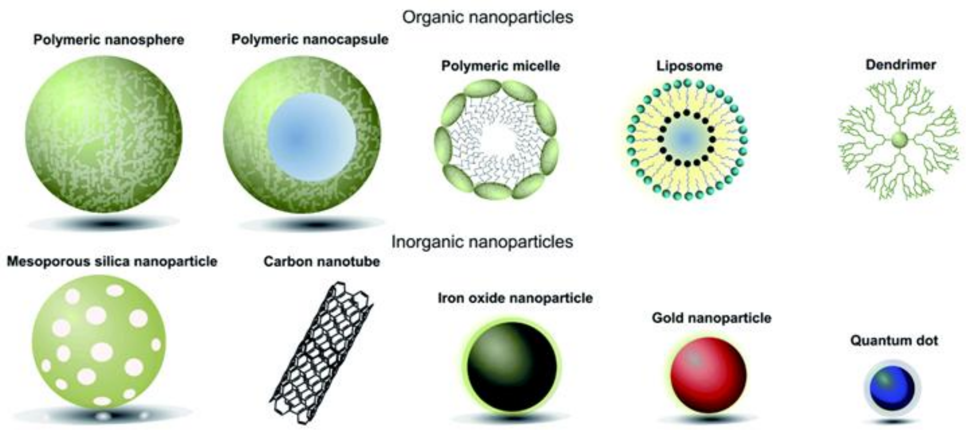

Fig. 1: Organic and Inorganic Nano particles

B. Inorganic nanoparticles

Particles that are not made up of carbon are inorganic nanoparticles. Nanoparticles based on metal and metal oxides are usually known as inorganic nanoparticles (Ealias&Saravanakumar , 2017).

Metal based:

Nanoparticles that are synthesized from metals to nanometric sizes by either destructive or constructive methods are nanoparticles based on metals (Ealias & Saravanakumar , 2017). They can synthesize almost all the metals into their nanoparticles (Salavati-niasari*et al*. 2008) (Ealias&Saravanakumar , 2017).Aluminium (Al), cadmium (Cd), cobalt (Co), copper (Cu), gold (Au), iron (Fe), lead (Pb), silver (Ag) and zinc are the metals widely used for nanoparticle synthesis (Zn). The nanoparticles have distinctive characteristics such as sizes from 10 to 100 nm, surface characteristics such as high volume to surface area ratio, pore size, density of surface charge and surface charge, crystalline and amorphous structures, shapes such as spherical and cylindrical and color, reactivity and sensitivity to environmental factors such as air, humidity, heat and sunlight, etc. (Ealias & Saravanakumar , 2017).

Metal oxides based:

Metal oxide-based nanoparticles are synthesized to change the properties of their respective metal-based nanoparticles, such as iron (Fe) nanoparticles that immediately oxidize iron oxide (Fe2O3) at room temperature in the presence of oxygen, which increases its reactivity compared to iron nanoparticles.Metal oxide nanoparticles are synthesized primarily because of their increased efficiency and reactivity (Tai *et al*. 2007).Aluminium oxide (Al2O3), cerium oxide (CeO2), iron oxide (Fe2O3), magnetite (Fe3O4), silicon dioxide (SiO2), titanium oxide (TiO2), and zinc oxide are frequently synthesized (ZnO) (Ealias & Saravanakumar , 2017). As compared to their metal equivalents, these nanoparticles have extraordinary properties (Ealias&Saravanakumar , 2017).

C. Carbon based

Nanoparticles made entirely of carbon are known as carbon dependent nanoparticles. They can be categorized into nano size fullerenes, graphene, carbon nano tubes (CNT), carbon nanofibers and carbon black and sometimes activated carbon and are shown in Figure 2 (Ealias & Saravanakumar , 2017).

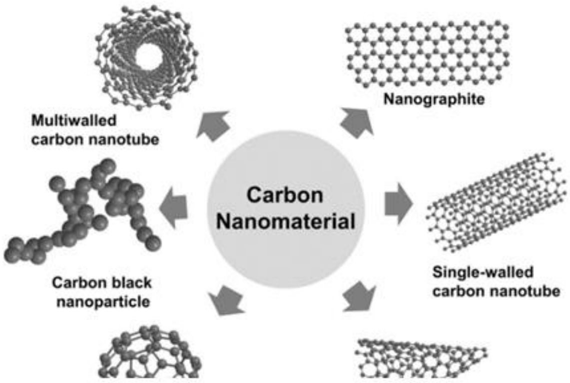

Fig. 2: Carbon Nanoparticles

Fullerenes:
Fullerenes (C60) is a spherical carbon molecule that is composed of carbon atoms kept together by hybridization of sp2. The spherical structure shapes approximately 28 to 1500 carbon atoms with diameters of up to 8.2 nm for a single layer and 4 to 36 nm for multilayer fullerenes (Ealias&Saravanakumar , 2017).

Graphene:
Graphene is a carbon allotrope. Graphene is a hexagonal honeycomb lattice network made up of two-dimensional planar surface carbon atoms. The thickness of the graphene sheet is usually about 1 nm (Ealias&Saravanakumar, 2017).

Carbon Nano Tubes (CNT):

Carbon Nano Tubes (CNT) are wound into hollow cylinders to form nanotubes with diameters as low as 0.7 nm for a single layer and 100 nm for multi-layered CNT and with a length varying from a few micrometers to many millimeters. A graphenenanofoil with a honeycomb lattice of carbon atoms (Ealias & Saravanakumar , 2017), The ends of a half fullerene molecule can either be hollow or closed (Ealias&Saravanakumar , 2017).

Carbon Nanofiber:
To manufacture carbon nanofiber, the same graphenenanofoils are used as CNT, but woven into a cone or cup shape instead of a normal cylindrical tube (Ealias&Saravanakumar , 2017).

Carbon black:

An amorphous carbon material, normally spherical in shape with diameters ranging from 20 to 70 nm. The interaction between the particles is so strong that aggregates are bound and agglomerates of around 500 nm are formed (Ealias&Saravanakumar , 2017).

Based on their morphology, size and chemical properties, NPs are broadly classified into different groups. Some of the well-recognized groups of NPs are given as below, based on physical and chemical characteristics (Khan, Saeed, & Khan, 2019).

Carbon-based NPs

Two main groups of carbon-based NPs reflect fullerenes and carbon nanotubes (CNTs). Fullerenes include nanomaterials consisting of hollow globular cages, such as allotropic carbon forms (Khan, Saeed, & Khan, 2019).Due to their electrical conductivity, high strength, structure, electron affinity, and flexibility, they have created remarkable commercial interest (Astefanei*et al*., 2015). These materials have pentagonal and hexagonal carbon units arranged, while each carbon is hybridized with sp2 (Khan, Saeed, & Khan, 2019).

CNTs are elongated, tubular, 1-2 nm in diameter structure (Ibrahim, 2013). These can be predicted as dependent on their diameter telicity as metallic or semiconducting (Aqel*et al*., 2012).

These are structurally identical to the rolling of graphite sheets. The laminated sheets may be single, double or multiple walls and are thus referred to as single-walled (SWNTs), double-walled (DWNTs) or multi-walled carbon nanotubes (MWNTs). They are commonly synthesized by carbon precursor deposition, in particular atomic carbons, vaporized from graphite to metal particles by laser or electric arc. They have recently been synthesized using the chemical vapor deposition (CVD) process (Elliott *et al*., 2013). These materials are not only used in pristine form, but are also used because of their unique physical, chemical and mechanical characteristics.

For several commercial applications, such as fillers (Saeed and Khan, 2016, 2014), effective gas adsorbents for environmental remediation (Ngoy*et al*., 2014), and as a support medium for various inorganic and organic catalysts, nanocomposites are often used (Mabena*et al.*, 2011; Khan, Saeed, & Khan, 2019).

Metal NPs:

Metal NPs are made solely from the precursors of metals. These NPs have distinctive optoelectrical properties due to well-known localized surface plasmon resonance (LSPR) characteristics.

Alkali and Noble Metals NPs, i.e. In the visible zone of the electromagnetic solar spectrum, Cu, Ag and Au have a wide absorption band (Khan, Saeed, & Khan, 2019). In today's cutting edge materials, the facet, size and shape controlled synthesis of metal NPs is essential (Dreaden*et al*.., 2012). Metal NPs are finding applications in many research areas due to their advanced optical properties. The coating of gold NPs is commonly used to sample SEM to improve the electronic stream, which helps to obtain high-quality SEM images. Many other applications are addressed in detail in the Applications section of this review (Khan, Saeed, & Khan, 2019).

Ceramics NPs:

Ceramic NPs are inorganic nonmetallic solids, synthesized by heat and successive cooling. You will find them in amorphous, thick, brittle, polycrystalline or hollow forms (Sigmund *et al*., 2006).These NPs are therefore attracting great attention from researchers due to their use in applications such as catalysis, photocatalysis, photodegradation of dyes, and imaging applications. (Khan, Saeed, & Khan2019; Thomas *et al*. 2015).

Semiconductor NPs:

Semiconductor materials have properties between metals and non-metals and have found distinct applications in the literature because of this property (Ali *et al*., 2017; Khan *et al*., 2017a). Semiconductor NPs have large bandgaps and have thus shown substantial improvements in the properties of their bandgap tuning. Photocatalysis materials, photo optics and electronic devices are therefore very important (Sun, 2000). As an example, various semiconductor NPs are found to be exceptionally efficient in water splitting applications due to their acceptable bandgap and bandedge positions (Hisatomi*et al*., 2014; Khan, Saeed, & Khan, 2019).

Polymeric NPs:

These are usually organic based NPs and a special term polymer nanoparticle (PNP) collective is used for it in the literature. Most of them are nanospheres or nanocapsular-shaped (Mansha*et al*., 2017).The former are matrix particles whose mass is normally solid overall, and the other molecules are adsorbed at the spherical surface's outer boundary. In the latter case, the solid mass is completely encapsulated inside the particle (Rao and Geckeler, 2011). The PNPs are readily functionalized in the literature and thus find bundles of applications (AbdEllah and Abouelmagd, 2016; Abouelmagd*et al*., 2016; Khan, Saeed, & Khan, 2019).

Lipid-based NPs:

In many biomedical applications, these NPs contain lipid moieties and are effectively used. Generally, a lipid NP with a diameter varying from 10 to 1000 nm is characteristically spherical. Like polymeric NPs, lipid NPs have a solid lipid center and soluble lipophilic molecules contain a matrix. Surfactants or emulsifiers have stabilized these NPs' external heart (Rawat*et al.*, 2011). A special area is lipid nanotechnology (Mashaghi*et al*., 2013), which focuses on the design and synthesis of lipid NPs for various applications such as drug carriers and delivery (Puri*et al*., 2009) and the release of RNA in cancer therapy (Gujrati *et al*., 2014; Khan, Saeed, & Khan, 2019).

IV. SYNTHESIS OF NANOPARTICLES:

For the synthesis of NPs, different methods may be used, but these methods are divided narrowly into two key groups i.e. (1) Bottom-up approach and (2) Top-down approach (Wang and Xia, 2004). These methods are further divided into separate subclasses based on process, reaction status and protocols adopted (Khan, Saeed, & Khan, 2019).

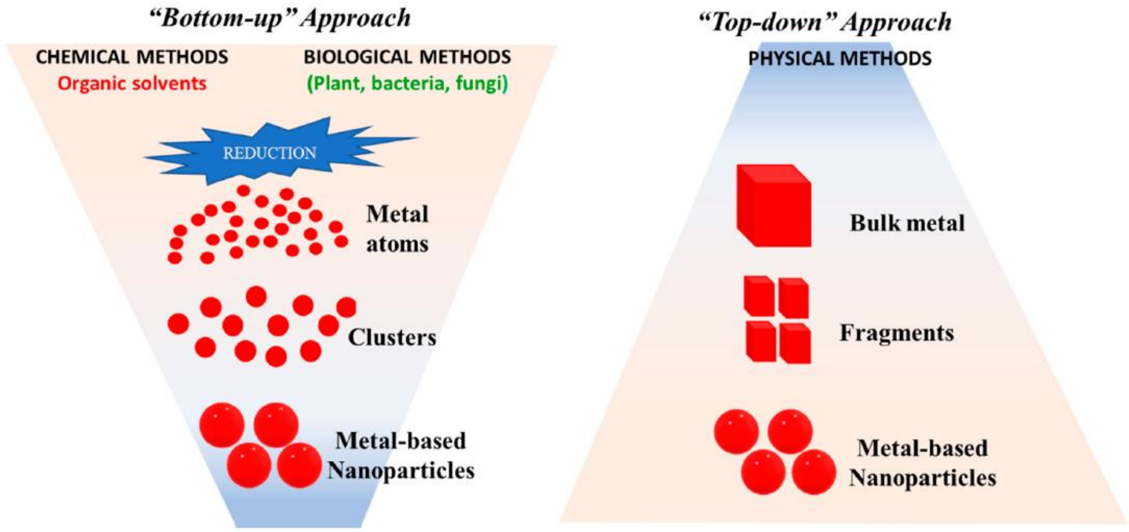

Fig. 2: Various methods of Nanoparticle synthesis.

A. Bottom-up method

The build-up of material from atoms to clusters to nanoparticles is the bottom-up or positive process. The most widely used bottom-up methods for nanoparticle processing are sol-gel, spinning, chemical vapour deposition (CVD), pyrolysis and biosynthesis (Ealias&Saravanakumar , 2017).

Grinding/milling, CVD, physical vapor deposition (PVD) and other techniques for decomposition are examples of this process (Iravani, 2011). This process is used to synthesize NPs from the coconut shell (CS) (Khan, Saeed, & Khan, 2019). For this reason, the milling method was used, and the raw CS powders were finely milled with the help of ceramic balls and a well-known planetary mill for different intervals of time (Khan, Saeed, & Khan, 2019).They demonstrated the effect of milling time by various characterization techniques on the overall size of the NPs. As estimated by the Scherer equation, it was determined that the NPs crystallite size decreases with time increases (Khan, Saeed, & Khan, 2019).They also recognized that the brownish color faded away with each hour increase due to the size reduction of the NPs (Khan, Saeed, & Khan, 2019). The SEM findings were also in accordance with the Xray trend, which also showed a decrease in particle size over time (Bello *et al*.., 2015; Khan, Saeed, & Khan, 2019).

Sol-gel:

The sol-a colloidal solution in a liquid form with solids suspended. The gel is a heavy macromolecule which is immersed in a solvent. Because of its simplicity, Sol-gel is the most favoured bottom-up approach and because most of the nanoparticles can be synthesized from this method (Ealias&Saravanakumar , 2017). It is a wet-chemical process with a chemical solution that serves as a precursor to an integrated discrete particle system (Ealias&Saravanakumar , 2017). The commonly used precursors in the sol-gel process are metal oxides and chlorides (Ramesh. 2013). In a host liquid, the precursor is then dispersed either by shaking, stirring or sonication, and there is a liquid and a solid phase in the resulting system. A phase separation is carried out by various techniques such as sedimentation, filtration and centrifugation to recover the nanoparticles and the moisture is further separated by drying (Mann *et al*. 1997; Ealias&Saravanakumar , 2017).

Spinning:

A spinning disc reactor conducts the synthesis of nanoparticles by spinning (SDR). In a chamber/reactor, it contains a rotating disc where physical parameters such as temperature can be controlled (Ealias&Saravanakumar , 2017). To extract oxygen inside and prevent chemical reactions, the reactor is normally filled with nitrogen or other inert gases (Ealias&Saravanakumar , 2017). The disk is rotated at various speeds where the liquid is pumped in, i.e. the precursor and water (Ealias&Saravanakumar , 2017). Spinning allows the atoms or molecules to combine and precipitate, accumulate and dry together (Mohammadi*et al*. 2014). The characteristics of nanoparticles synthesized from SDRR are determined by different operating parameters, such as liquid flow rate, disc rotation speed, liquid/precursor ratio, feed position, disc surface, etc (Ealias&Saravanakumar , 2017).

Chemical Vapour Deposition (CVD):

The deposition of a thin film of gaseous reactants onto a substrate is chemical vapour deposition. The deposition is carried out in an ambient temperature reaction chamber by mixing gas molecules (Ealias&Saravanakumar , 2017). When a hot substrate comes into contact with the combined gas, a chemical reaction happens (Bhaviripudi*et al*. 2007; Ealias&Saravanakumar , 2017). This reaction produces a thin film of the product that is recovered and used on the substrate surface (Ealias&Saravanakumar , 2017).The influencing factor in CVD is substrate temperature. The benefits of CVD are that nanoparticles are extremely pure, uniform, hard and solid (Ealias&Saravanakumar , 2017). The drawbacks of CVD are the need for special equipment and highly radioactive gaseous by-products (Ealias&Saravanakumar , 2017).

Pyrolysis:

Pyrolysis is the most widely used method for nanoparticle processing in large-scale industries. It requires burning a flame precursor with (Ealias&Saravanakumar , 2017). The precursor is either liquid or vapor, which is fed into the furnace through a small hole where it burns at high pressure (Kammler*et al*. 2001; Ealias&Saravanakumar , 2017). In order to retrieve the nanoparticles, the combustion or by-product gases are then classified into air. To generate high temperatures for fast evaporation, some of the furnaces use laser and plasma instead of flame (Amato 2013; Ealias&Saravanakumar , 2017).The benefits of pyrolysis are simple, reliable, cost-effective and ongoing high-yield processes (Ealias&Saravanakumar , 2017).

Biosynthesis:

Biosynthesis is a renewable and environmentally sustainable approach to the synthesis of non-toxic and biodegradable nanoparticles (Kuppusamy 2014; Ealias&Saravanakumar , 2017). Biosynthesis uses bacteria, plant extracts, fungi, etc. along with precursors to generate nanoparticles for bioreduction and capping purposes instead of traditional chemicals (Ealias&Saravanakumar , 2017). Biosynthesized nanoparticles have distinctive and improved properties that are used in biomedical applications (Hasan 2015; Ealias&Saravanakumar , 2017).

B.Top-down method

The reduction of a bulk substance to nanometric scale particles is a top-down or destructive approach. Some of the most commonly used nanoparticle synthesis methods are mechanical milling, nanolithography, laser ablation, sputtering and thermal decomposition (Ealias&Saravanakumar , 2017).

Mechanical milling:

Mechanical milling is the most commonly used of the numerous top-down methods for generating different nanoparticles(Ealias&Saravanakumar , 2017). Mechanical milling is used during synthesis to mill and post-anneal nanoparticles where various elements are milled in an inert atmosphere (Yadav *et al*. 2012; Ealias&Saravanakumar , 2017).Plastic deformation leads to particle shape, fracturing leads to a decrease in particle size and cold-welding leads to an increase in particle size. The driving factors in mechanical milling (Ealias&Saravanakumar , 2017) .

Nanolithography:

The study of the manufacture of nanometric scale structures with a minimum of one dimension in the size range of 1 to 100 nm is nanolithography. For example, optical, electron-beam, multiphoton, nanoimprint, and scanning probe lithography are different nanolithographic processes (Ealias&Saravanakumar , 2017). Generally, lithography is the method of printing on a light sensitive material a necessary shape or structure that selectively extracts a portion of the material to produce the desired shape and structure (Ealias&Saravanakumar , 2017).The drawbacks are the need for sophisticated equipment and the related costs (Hulteen*et al*. 1999; Ealias&Saravanakumar , 2017).

Laser ablation:

A common method for the production of nanoparticles from different solvents is laser ablation synthesis in solution (LASiS) (Ealias&Saravanakumar , 2017). A plasma plume producing nanoparticles condenses the irradiation of a metal immersed by a laser beam in a liquid solution (Amendola and Meneghetti

2009; Ealias&Saravanakumar , 2017).It is a reliable top-down approach that provides nanoparticles based on synthesis metal to provide an alternative solution to traditional chemical reduction of metals. It is a 'green' method because LASiS offers a stable synthesis of nanoparticles in organic solvents and water that does not need any stabilizing agent or chemicals (Ealias&Saravanakumar , 2017).

Sputtering:

Sputtering is the accumulation on a surface of nanoparticles by expelling particles from it by clashing with ions (Shah and Gavrin 2009; Ealias&Saravanakumar , 2017). The deposition of a thin layer of nanoparticles accompanied by annealing is usually sputtering.The shape and size of the nanoparticles is determined by the thickness of the coating, temperature and annealing time, substrate form, etc (Lugscheider*et al*. 1998; Ealias&Saravanakumar , 2017).

Thermal decomposition:

Thermal decomposition is a heat-produced endothermic chemical decomposition that breaks the chemical bonds in the compound (Salavati-niasari*et al*. 2008; Ealias&Saravanakumar , 2017). The exact temperature at which an element decomposes chemically is the temperature of decomposition (Ealias&Saravanakumar , 2017).By decomposing the metal at specific temperatures undergoing a chemical reaction generating secondary products, the nanoparticles are generated (Ealias&Saravanakumar , 2017). Some of the nanoparticles synthesized from these approaches are mentioned in Table 1. (Ealias&Saravanakumar , 2017).

Table.1: Different synthesis methods of different Nanoparticles.

Types of Nanoparticles	Method	Category of synthesis
Carbon, metal and metal oxide based	Sol-gel	Bottom-up
Organic polymers	Spinning	
Carbon and metal based	Chemical Vapour Deposition (CVD)	
Carbon and metal oxide based	Pyrolysis	
Organic polymers and metal based	Biosynthesis	
Metal, oxide and polymer based	Mechanical milling	Top-down
Metal based	Nanolithography, Sputtering	
Carbon based and metal oxide based	Laser ablation, Thermal decomposition	

V. ANTIMICROBIAL ACTIVITY OF DIFFERENT NANO PARTICLES:

Although metal NPs have different methods of synthesis, all metal NPs show substantial crystallinity, high surface area and reactive surfaces (Hoseinzadeh, *et al*., 2017). In the emerging nanotechnology sector, the objective is to build nanostructures or nano-arrays with unique characteristics for bulk or single particle organisms (Seil*et al*. 2012).Because of their small size and high density of corner or edge surface sites, oxide NPs may exhibit unusual physical and chemical characteristics. Metal oxide NPs are believed to exhibit antimicrobial activities (Dizaj*et al*. 2014).Accessible studies suggest that several of the NPs of metal oxides (e.g., Al_2O_3, TiO_2, ZnO, CuO, CO_3O_4, In_2O_3, MgO, SiO_2, ZrO_2, Cr_2O_3, Ni_2O_3, Mn_2O_3, CoO, and Nickel Oxide NPs) are toxic to many microorganisms and have been able to destroy several bacteria successfully.At efficient concentrations used to destroy bacterial cells, most metal oxide NPs have no toxicity to humans, thereby becoming a benefit for full-scale use of them (Hajipour*et al*. 2012; Hoseinzadeh, *et al*., 2017).

It has been suggested that bacteria are unable to establish antimicrobial resistance to metal NPs, based on the proposed antimicrobial mechanisms of NPs and documented studies (Dizaj*et al*. 2014, Hajipour*et al*. 2012).Compared to traditional antimicrobial agents, the use of NPs as antimicrobial agents has the benefits of low cost and easy preparation, high performance and less time to destroy and overcome microbial resistance (Hoseinzadeh*et al*. 2012, Hoseinzadeh*et al*. 2014; Hoseinzadeh, *et al*., 2017).Nevertheless, the production of antimicrobial agents using NPs is seen as the way of the future, which will offer many benefits to anyone who will use it, nothing is ever perfect and it will always have pros and cons (Hoseinzadeh, *et al*., 2017).

Due to their shape-and-size-dependent tunable properties, metallic nanoparticles have become a key focus for many biomedical applications, including antimicrobials (Singh, Garg, Pandit, Mokkapati, &Mijakovic, 2018). Due to their antimicrobial existence, metallic nanoparticles such as silver, copper, titanium, zinc, and iron may be used against MDR microorganisms(Huh *et al.* 2011, Fernandez-Moure*et al.* 2017). Importantly, biogenic nanoparticles are primarily used due to their long-term stability and biocompatibility for antimicrobial applications. Oxidative stress, metal ion release, and non-oxidative stress occurring concurrently are the processes behind the antimicrobial effect of these nanoparticles (Zaidi *et al*. 2017; Singh, Garg, Pandit, Mokkapati, &Mijakovic, 2018).For antimicrobial applications against several pathogenic microorganisms, there are many examples where green metallic nanoparticles obtained from microorganisms have been explored.Biogenic AgNPs obtained from Brevibacteriumfrigoritolerans DC2 (Singh *et al*. 2015), SporosarcinakoreensisDC4 (Singh *et al*. 2016), and Bhargavaeaindica DC1 (Singh *et al*. 2015), for example, demonstrated antimicrobial activity against Vibrio parahaemolyticus, Salmonella enterica, Bacillus anthracis, Escherichia coli, and Candida albicans.Antimicrobial activity against Escherichia coli, Proteus vulgaris and Staphylococcus aureusus was detected in copper nanoparticles (CuNPs) obtained from Sidaacuta (Sathiyavimal*et al*. 2018). Furthermore, these nanoparticles demonstrated an increase in the antimicrobial efficacy of traditional antibiotics such as lincomycin, oleandomycin, vancomycin, novobiocin, penicillin G and rifampicin when co-administered.Zinc oxide research also disclosed its antibacterial activity against *S. aureus, E. Coli*, as well as *P. aeruginosa* (Pasquet*et al*. 2014; Singh, Garg, Pandit, Mokkapati, &Mijakovic, 2018). The results therefore indicate that combining current antibiotics with green metallic nanoparticles can be further helpful in improving their antimicrobial efficacy (Singh, Garg, Pandit, Mokkapati, & Mijakovic, 2018).

It is easy to enumerate the benefits and drawbacks of NP antimicrobials, and some of them are listed here:

VI. ADVANTAGES OF NP ANTIMICROBIAL AGENTS:

A novel and talented strategy, which is an efficient and low-cost measure against pathogenic bacterial cells, is to use NPs against bacterial cells as an antimicrobial agent. In short, the perks
The following are NP antimicrobial agents (Hoseinzadeh, *et al*., 2017):

1.In special physicochemical conditions, magnetic field, light, temperature, and pH values, they can be triggered by considering the stimulus for the desired state, such as engineered active stimulus. NPs can also be useful in acidic media, decreasing the efficacy of traditional chemical antimicrobials (Hoseinzadeh, *et al*., 2017).

2. NPs can penetrate into bacterial cells easily. NPs are small with variable sizes and made of different materials, so it is possible to choose acceptable NPs that could pass through cell barriers and cause cell disruption (Hoseinzadeh, *et al*., 2017).
3.Owing to the flexible physico-chemical properties of NPs, the side effects of their use can be minimised.
4. NP antimicrobials with various bacterial pathways are capable of overcoming traditional resistance (Hoseinzadeh, *et al*., 2017).
Antimicrobial resistance may result from a change or inactivation by the bacteria of the antimicrobial agent, a change in the specific position of the antibiotic, a change in the metabolic pathway to prevent the destructive effect of the antimicrobial agent, and a decrease in the accumulation of the antimicrobial agent by minimizing its entry or by optimizing cell clearance. However, few microbes have the ability to decrease absorption (such as *Cupriavidusmetallidurans* CH_{34} versus TiO_2 and Al_2O_3 NPs) or increase NP efflux (such as *Shewanellaoneidensis* versus Cu NPs by developing extracellular polymer substances) resulting in resistance to them (Hoseinzadeh, *et al*., 2017).

VII. DISADVANTAGES OF NP ANTIMICROBIALS

While NP antimicrobials have many benefits and advances in the control of pathogenic bacteria, the use of this antimicrobial agent for formal use is likely to be challenging and some of them are as follows (Hoseinzadeh, *et al*., 2017):
• As a result of their use and harmful impact of NPs on cells, tissues, and organs, unknown health effects of liberated NPs (Hoseinzadeh, *et al*., 2017).
• Toxicity of NPs against microorganisms that are untargeted.
• NPs are stable in the atmosphere and can accumulate. They can be transmitted by air or water and cause many health problems. Comprehensive laboratory research, therefore, is
Warranted to use them before (Hoseinzadeh, *et al*., 2017).

• NP agglomeration, as a result of which the scale could be altered. Small NPs are known to have the greatest bactericidal effect. On the other hand, the size-dependent antimicrobial potential of NPs is (Hoseinzadeh, *et al*., 2017).

VIII. EFFECTIVE FACTORS OF NP ANTIMICROBIALS AGAINST BACTERIA

The capacity of NPs to minimize or destroy cells may be affected by certain successful factors, and there are mechanisms for NPs against bacteria that are briefly described as follows (Hoseinzadeh, *et al*., 2017):

Surface Charge of the Metal NPs

NPs bind easily with a negative charge to the bacterial cell wall and facilitate penetration into the membrane, which can lead to increased NP absorption or attraction to bacteria, resulting in greater effectiveness (Young *et al*. 2016; Hoseinzadeh, *et al*., 2017). On the other side, because of electrostatic force, aggregation of the particles on the bacterial surface occurs. The potential of Zeta, along with particle size and chemistry, can be considered a highly important antimicrobial impact control parameter (Hoseinzadeh, *et al*., 2017).Therefore, due to reduced contact between the NPs and bacteria, the repulsion between bacteria and negatively charged NPs may result from the formation of an electrostatic barrier. The antibacterial activity would increase with a decrease in the magnitude of the negatively charged NPs (Hoseinzadeh*et al*. 2014; Young *et al*. 2016; Hoseinzadeh, *et al*., 2017).

Other variables contributing to possible changes in NP antimicrobial activity are surface alteration and functionalization (Wang *et al*. 2015). The presence of oxygen atoms on the NP surface can be increased by some functionalization that can lead to more reactive oxygen species (ROS) production in the medium. As a result of NP alteration, it is possible to release ions from NPs, which therefore enhances NP antimicrobial activity through the process of ion toxicity (Hoseinzadeh, *et al*., 2017).

Shape of NPs

Numerous studies have shown that the form of NPs affects the antimicrobial capacity (Zhang *et al*. 2016; Hoseinzadeh, *et al*., 2017). The synthesizing process, the control of used solvents and concentration, polymers and bio-molecules, as well as small molecules such as adsorbed gas and even atomic species, such as various metal ions, precursor natures, temperature and pH of the preparation state, may facilitate the control of NP form (Hoseinzadeh, *et al*., 2017). High atom density (e.g., 111 for nanoZnO) can result in the shape of the NP (Hoseinzadeh*et al*. 2014; Hoseinzadeh, *et al*., 2017).Researchers have studied different types of NP such as spherical, rod-shaped, truncated triangular, nanotubes, nanorods, nanowires, nanosphere, nanoneedles and nanorings (Fazio *et al*. 2016; Hoseinzadeh, *et al*., 2017).The shape-dependent antimicrobial properties of NPs have generally been revealed by documented studies. There are unique structural, optical, electrical, and physicochemical properties of each nanostructure, enabling remarkable applications. A certain action mechanism is accounted for by each morphology (Hoseinzadeh, *et al*., 2017).These distinct morphologies show a pronounced antibacterial impact on the bacteria being attacked. The O:metal ratio on the surface of NPs in the oxide form of metallic NPs (such as ZnO) will affect the generation of ROS, which is under the influence of the amount of oxygen atoms on the surface of the NP and also depends on the shape of the NPs (Hoseinzadeh*et al*. 2014; Hoseinzadeh, *et al*., 2017).

Type and Material of NPs

One of the significant parameters affecting the resulting antimicrobial efficacy is the kind of materials used to prepare the NPs. The toxicity of metal oxide NPs parent heavy metals can have a high effect on their antimicrobial activity (Dizaj*et al*. 2014; Hoseinzadeh, *et al*., 2017). The forms of NPs predominate in each mechanism. For instance, as a result of external membrane damage, Ag NP may disrupt bacteria (Hoseinzadeh, *et al*., 2017). In addition, bacterial cell killing is possible due to metabolic process disruption caused by the interaction of the released Ag ion with disulfide or sulfhydryl enzyme groups (Hoseinzadeh, *et al*., 2017). In the case of ZnO NPs, the primary routes of ZnO NP contact with bacteria cells are ROS generation on the surface of the particles, zinc ion release, membrane malfunction, NP internalization, and surface charge of NPs (Hoseinzadeh*et al*. 2012; Hoseinzadeh, *et al*., 2017).

Concentration of NPs

NPs demonstrate greater antibacterial activity in higher concentrations (Hoseinzadeh, *et al*., 2017). It may be linked to mitochondrial dysfunction, increased cell leakage of lactate dehydrogenase, and an excessive effect of NP on the same bacterial populations (Hoseinzadeh*et al*. 2014).In addition, the greater surface area means higher NP concentrations, resulting in possible antimicrobial NP activity (Hoseinzadeh, *et al*., 2017).

Table.2: Nano-antimicrobial activity (Hoseinzadeh, et al., 2017):

Nanoparticle	Activity	Target	Reference
Silver nanoparticle	Antibacterial activities were proportional to size, and higher activities were performed by the smaller particles.	*Escherichia coli* (K12 strain, MG1655)	Lok *et al*..2007
four types of graphene-based materials: graphite (Gt) graphite oxide (GtO) graphene oxide (GO) reduced graphene oxide (rGO)	GO dispersion demonstrates the strongest antibacterial activity under identical conditions, sequentially accompanied by rGO, Gt, and GtO.	*Escherichia coli*	Liu *et al*.. 2011
nano- and micro-scaled oxide particles aluminum (Al2O3) silicon (SiO2) titanium (TiO2)	Higher toxicity was seen in titanium oxide. In comparison, instead of Al2O3, SiO2, ZnO toxicity was the most toxic, causing 100 percent mortality for the three bacteria studied. Al2O3 nanoparticles had a mortality rate of 57% to B. subtilis, 36% to	*Bacillus subtilis, Escherichia coli* and *Pseudomonas fluorescens*	Jiang *et al*.. 2009

zinc oxides (ZnO)	E. coli, and 70% to P. fuorescens. SiO2 nanoparticles killed 40% of B. subtilis, 58% of E. coli, and 70% of P. fluorescens.		
M@TiO2 nanocomposites (M = Ag, Pd, Au, Pt)	Antibacterial results have shown that the TiO2 matrix presence improves the antibacterial effect of silver nanoparticles and increases the growth of E. It can be completely inhibited by coli.	Gram-negative *Escherichia coli*	Chen *et al.*. 2010
Zinc oxide nanoparticles	The zinc oxide nanoparticle has been used to create antimicrobial textiles. The findings showed that there was substantial antibacterial activity against S. aureus in the finished fabric.	*Staphylococcus aureus*	Rajendra *et al.*. 2010
Nano- Cerium Oxide	The good antimicrobial activity of cerium oxide was demonstrated by the result.	Gram-negative *Escherichia coli*	Kuang*et al.*. 2011
Nano-composite MgO	Compared with other antibacterial materials, the magnesium oxide nano-composite demonstrated unique antibacterial activity.		Li *et al.*.2005
Silver Nanoparticles (AgNPs)	In both cell models, exposure to AgNPs or far lower levels of Ag ions has been found to contribute to dose-dependent inhibition of selenium metabolism.	keratinocyte cell model (HaCat) and a lung cell model (A549)	Srivastava *et al.*. 2012
sophorolipid reduced/capped silver nanoparticles	It has been shown that for both Gram-positive and -negative bacteria, the sophorolipid capped Ag nanoparticles can be highly potent antibacterial agents.	Gram-positive and Gram negative bacteria	Singh *et al.*. 2009
ZnOnanoparticle	Tests for disk diffusion, minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) indicated that ZnOnanoparticle could be used to regulate water systems.	*Escherichia coli*	Masoumbaigi *et al.*. 2015
Nanocrystalline MgO	The outcome showed that the antimicrobial activity was strong.	*Escherichia coli* (Gram negative) and *Staphylococcus aureus* (Gram positive)	Makhluf *et al.*. 2005

IX. THE PROBLEMS ASSOCIATED WITH THE USE OF NANO PARTICLES AS ANTIMICROBIAL AGENT:

Significant factors are porosity, morphology, concentration, particle size, temperature, aeration, and pH. Temperature, aeration, and pH of NPs and bacteria containing medium may affect the agglomeration of NP (Hoseinzadeh, *et al*., 2017). In this way, elevated temperatures, high-level aeration and decreased medium pH will contribute to an increase in the antibacterial activity of NP. Agglomerated NPs have a low surface area that contributes to lower antimicrobial activity, including other associated mechanisms (Hoseinzadeh, *et al*., 2017).

X. ESTABLISH A COMPARISON BETWEEN ANTIBIOTICS AND NANOPARTICLES AS ANTIMICROBIAL AGENT

A comparative study of biological and chemical nanoparticles has shown that biological nanoparticles have a greater antimicrobial effect than chemically synthesized nanoparticles (Singh, Garg, Pandit, Mokkapati, &Mijakovic, 2018). Sudhasree*et al*, for instance,.. It was suggested that Desmodiumgangeticum's biological synthesized nickel nanoparticles are more monodispersed and have higher LLC PK1 (epithelial cell lines) antioxidant, antibacterial, and biocompatible activities than chemically synthesized nanoparticles. For antibacterial activity, al the microorganisms tested both the nanoparticles against *Staphylococcus aureus*, *Klebsiella. pneumonia*, *Pseudomonas aeruginosa*, *Vibrio cholerae*, and *Proteus vulgaris*, and found that chemically synthesized nickel nanoparticles were not at all active against *K. pneumonia*, *Pseudomonas aeruginosa* and *P. vulgaris*, whereas biological nanoparticles showed antimicrobial activity against these microorganisms. For *Staphyllococcusaureus*, chemical nanoparticles were less active than the biological ones. However, in the case of *Vibrio cholerae*, chemical nanoparticles were more effective (Mukherjee *et al.* 2012; Singh, Garg, Pandit, Mokkapati, & Mijakovic, 2018). Researchers also described how biologically synthesized zinc nanoparticles have more antimicrobial potential against *Salmonella typhimurium* ATCC 14028, B. subtilis ATCC 6633, and *Micrococcus luteus* ATCC 9341 compared with chemically synthesized zinc nanoparticles (Singh *et al.* 2016; Singh, Garg, Pandit, Mokkapati, & Mijakovic, 2018).

XI. CONCLUSION:

It should be considered that several aspects are mainly taken into account when using nanomaterials as antimicrobial agents. The long production-consumption cycle can lead to antibacterial resistance to common chemical antibacterial agents, thereby reducing their efficiency and the use of low quality or fake medicines in undeveloped and developing countries. The new solution to this challenge has been NPs as an antimicrobial agent, which can create an effective nanostructure to deliver the antimicrobial agent efficiently to the bacterial community; moreover, they are so potent that microbial pathogens can not build resistance to them. On the other hand, at successful concentrations used to destroy bacterial cells, most of the metal oxides NPs do not have toxicity to humans, which thus becomes a benefit for full scale use. Over the current decade, however, numerous reports have indicated that NPs, at least at the research level, are excellent antibacterial agents.

In summary, we would like to conclude that microorganisms are generally able to develop resistance to antibiotics due to poor diagnosis and overdose and drug disability. A serious global healthcare problem is the infections caused by MDR microorganisms. Biogenic metallic nanoparticles have been designed to solve these problems and have shown good efficacy against different MDR pathogens, either individually or in combination with antibiotics.However, some significant facts that need to be addressed in order to use these nanoparticles for therapeutic applications are the distribution of nano particles, their bioavailability, successful targeting, and the excretion of nanoparticles from the body if taken as a drug carrier to treat site-specific infections.

Due to the antimicrobial nature of metallic nanoparticles, applications are not only limited to the biomedical field, but can also be applied to the areas of water treatment, textiles, food packaging, cosmetics, agriculture (nano-pesticides and nano-fertilizers), cell phone self-cleaning coatings, washing machines, and computer keyboards.The biogenic nanoparticles for these applications, however, have not yet been commercialized.Finding the right balance between the cost of processing, scalability, and their applicability is the real challenge for biogenic nanoparticles. Therefore, a great deal of research will be needed in this respect to concentrate on economic ways of producing biogenic nanoparticles that will make them readily accessible.
For all sorts of potential applications that are either applicable to the antimicrobial period or otherwise.

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