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NANOTECHNOLOGY STRATEGY AS ANTIBACTERIAL: A PRIMER FOR THE NOTICE

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ABSTRACT

Multidrug-resistant (MDR) bacteria pose a major threat to all fields of medical science as it can result in treatment failure which can have severe consequences, especially in case of critical patients. The availability of new antibacterial agents appeared to be a very complex process. One of the most important aspect of modern field research is nanotechnology, it deals with synthesis, design and manipulation of particles structures ranging from approximately 1-100nm. Nanoparticles (NPs) are of great importance in areas like health care, cosmetics, food and feed, environmental health e.t.c. Nanoparticles matrix properties and constituent materials can be used to categorized them into inorganic and organic nanosystems. Techniques use within the synthesis of NPs includes; chemical, physical, chemistry, and biological methods, every methodology has its advantages and disadvantages with common issues of value, quantifiability and uniform particle size. Famous microbiologist Alexander Fleming said that “There is probably no chemotherapeutic drug to which in suitable circumstances the bacteria can not react by in some way acquiring fastness.” thus, there's high chance that the organism can also become resistance to newly developed medication at later stage. To this end NPs are considered to be good antibacterial agents and may overcome the barrier of MDR owing to their ability to anchor to the bacterial cell wall, multifunctional mechanisms to intervene normal cell functionality and subsequently penetrate it, thereby causing structural changes in the cell membrane permeability leading to cell death.

Keywords: Nanoparticles, Multidrug-resistant, medication, Nanosystems, bacteria cell, Cell death

INTRODUCTION

The development of a new antibacterial agents cropped up to be a complex process in view of the capability to produce effective drugs with no or reduce side effects, in addition to the high production costs and the time required for approval of new drugs that takes regarding 10–15 years **(Wang *et al.*, 2017; Patra *et al.*, 2018; Singh *et al.*, 2014).**
Nanoparticle has surrounding interfacial layer with particles between 1 and 100 nanometres (nm) in size. The interfacial layer is an integral part of nanoscale matter, fundamentally affecting all of its properties **(Singh *et al.*, 2016).** Ions, inorganic and organic molecules are major constituents of their interfacial layer typically. Organic molecules coating inorganic nanoparticles are known as stabilizers, capping and surface ligands, or passivating agents **(Singh *et al.*, 2016).**
Nanomedicine plays a vital role in enhancing the effectiveness of existent therapeutics, by enhancing the physicochemical properties and stability of antibiotics, offering a chance of biofilm internalization, prolongation of antibiotic release, additionally to the potential of targeted delivery to the location of infection and improved circulation with a ensuant reduction of the connected facet effects compared to the corresponding free medication **(Natan *et al.*, 2017).**

Nanoparticles

Nanotechnology is an important field of modern research dealing with design, synthesis, and manipulation of particle structures ranging from approximately 1-100 nm. Nanoparticles (NPs) have wide range of applications in areas such as health care, cosmetics, food and feed, environmental health, mechanics, optics, biomedical sciences, chemical industries, electronics, space industries, drug-gene delivery, energy science, optoelectronics, catalysis, single electron transistors, light emitters, nonlinear optical devices, and photo-electrochemical applications.
Nanoparticles is product of materials of various chemical nature like biomolecules, non-oxide ceramics, polymers, organics, metal oxides, silicates, carbon and metals. Nanoparticles additionally exist in many totally different morphologies like spheres, cylinders, platelets and tubes **(Kim, J., 2007)**.
Nanoparticles is generally classified into 2, namely, organic nanoparticles that embrace carbon nanoparticles (fullerenes) and also the inorganic nanoparticles that embrace magnetic nanoparticles, metallic element nanoparticles (gold and silver) and Semi-conductor nanoparticles (titanium chemical compound and atomic number 30 oxide) **(Natan *et al.*, 2017)** Nano materials have distinctive chemical and biological properties as compared to their larger counterparts **(Shrivastava *et al.*, 2007)**. The properties of nanomaterials will greatly influence their interactions with bio molecules and cells, because of their peculiar chemical composition, surface structure, size, shape, charge, solubility and agglomeration. for instance, nanoparticle accustomed turn out exceptional pictures of tumour sites; single-walled carbon nanotubes, are used as high-efficiency delivery transporters for biomolecules into cells **(Varshney *et al.*, 2009)**. By additional analysis in technology, it is helpful for each facet of human life such as somatic cell analysis, regenerative drugs and nutraceuticals are among the leading sectors that may be changed by technology innovations. Silver NPs is an are of interest as a result of the distinctive properties (e.g. form and size relying electrical, magnetic properties and optical). which might be incorporated into cosmetics merchandise, composite fibers, antimicrobial applications, biosensor materials, refrigerant superconducting materials, and electronic parts **(Thu *et al.*, 2013)**. it's additionally helpful when incorporated into antimicrobial applications, biosensor materials, refrigerant super-conducting materials, composite fibers, cosmetic merchandise, and electronic parts. Some valuable applications of silver NPs are in medical specialty, medicine, and odontology e.t.c. many physical and chemical ways are used for synthesizing and stabilising silver nanoparticles **(Senapati *et al.*, 2005)**.

Classification of Nanosystems

Nanoparticles matrix properties and constituent materials can be used to categorized them into inorganic and organic nanosystems **(Baranwal *et al.*, 2018)**. Inorganic nanosystems are synthesis from inorganic oxides. Their synthesis technique depends on chemical reduction of metallic salts with a reducing agent. Environmental parameters, as an example pH scale and temperature, play a serious operate in determination of the specificities of those materials, aggregation, the in vitro drug release kinetics, consequently affecting their loading capacity and hence their antibacterial affect **(Ashik *et al.*, 2018)**. In addition, organic nanosystems like compound micelles, liposomes, lipid-based nanoparticles and compound nanoparticles have desirable biodegradability and biocompatibility options, making them appropriate candidates for clinical use **(Martin-Serrano *et al.*, 2019)**.

Organic Nanosystems

Liposomes nine Composition and Characteristics of Liposomes

Liposomes are the foremost extensively evaluated antimicrobial drug delivery nanosystemsThey are characterized by spherical structures made up of phospholipid bilayer(s) surrounding an inner aqueous

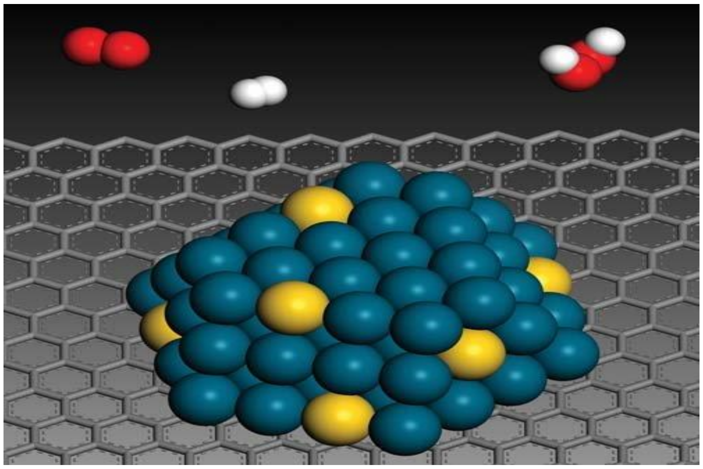

Figure 1 image showing nanoparticles of an alloy of gold (yellow) and palladium (blue) space, go in size from 0.02 to 10nm.

The effectuality of antibacterial-loaded liposomes in biofilm demolition depends on the chemical science properties of liposomes that manage their stability and in vivo interactions. Nanoparticle has small unilamellare vesicles of '100nm which allow antibiotic delivery helping them to display high capability in the eradication of bacterial strains. Liposomes proved to be useful for the management of topical, ocular bacterial infections, pulmonary, and vaginal **(Nermin *et al.*, 2020)**.

Advantages of Antibiotics-Loaded Liposomes as Drug Delivery Agents

- Better protection and enhanced antibiotics biodistribution.
- Selective biofilm targeting affinity.
- Improved selectivity towards intracellular and extracellular bacterial strains.

Bimetallic NPS

Ag and Au (Np) are also employed to reinforce the results of a drug and cut back the specified dose. They can also be used alone since they possess antimicrobial properties **(Singh *et al.*, 2016)**. AuNPs represent sensible vectors to the delivery of medical specialty compounds. Synergism of Au and Ag alloys is a great solution since they improved stability in advanced biological media provided by gold and combine the antimicrobial result of silver with the convenience of functionalization. Fakhri and colleagues synthetized and functionalized AgAuNPs with a antibacterial drug and over that there exists a synergistic result of the antibiotic with the bimetallic nanoparticle, with greater bactericidal activity of this form in detriment of its free forms **(Pedro *et al.*, 2018)**.

Silver Nanoparticles (AGNPS)

Since the traditional times, silver has been recognized as having antimicrobial effects **(Reidy *et al.*, 2013)**. supported all the proof thus far, AgNPs are as the most promising inorganic NPs which will be used for the treatment of bacterial infections **(Natan *et al.*, 2017)**. These NPs is also synthesized by ancient chemical reduction or via "green" chemistry approaches using plant and/or bacteria extracts **(Ribeiro *et al.*, 2018)**. many mechanisms are planned to grasp AgNPs mediate cellular death, together with cytomembrane disruption **(Pedro *et al.*, 2018)**, oxidization of cellular parts, inactivation of the metabolism chain enzymes, production of ROS, and decomposition of the cellular parts. The adsorption of the NPs leads to alteration of the negative charge of the cell wall and also the depolarization of the cell wall which make them to become more permeable. The entry of AgNPs induces ROS which will inhibit ATP production and DNA replication. However, there's proof that AgNPs will unharness Ag+, acknowledged to exhibit antimicrobial activity, when interacting with thiol-containing proteins, which weaken their functions. The precise technique of the antibacterial mechanism of AgNPs continues to be not utterly understood **(Pedro *et al.*, 2018)**. All the Previous studies shows that AgNPs exert many antibacterial activities, which can justify why bacteria resistance to silver is rare. considerations relating to the toxicity and genotoxicity of AgNPs are raised however numerous authors have conducted clinical trials supported AgNPs and no necessary clinical alterations are detected. curiously, AgNPs are found to exhibit higher antimicrobial activity than antibiotics like vancomycin or gentamicin against P. aeruginosa and MRSA **(Ribeiro *et al.*, 2018)**.

Gold Nanoparticles (AuNPs)

Metallic gold is considered as inert and non-toxic, which can vary once it shifts oxidation states (I and II) Gold NPs (AuNPs) is also synthesized by traditional chemical reduction of a gold salt or via "green" chemistry approaches by making use of plant and/or bacteria extracts. Gold nanoparticle alloy of yellow coloration are shown in Figure 1. The foremost used and represented technique is that the chemical synthesis supported the reduction of chloroauric acid by turn **(Fernandes *et al.*, 2017)**. Some studies have addressed the potential of making use of AuNPs as antibacterial agents, however some controversy still exists. in line with Yu H and collaborators, AuNPs AuNPs are usually not bactericidal at low concentrations and sapless antibacterial at high concentrations. This is often presumably because of the result of co-existing chemicals, like gold ions, surface coating agents, and chemicals concerned within the synthesis that weren't utterly removed. The antibacterial mechanism of AuNPs is associated to (i) the collapse within the membrane potential, impeding ATPase activity inflicting a deterioration of the cell metabolism; (ii) impeding of the binding monetary unit of the organelle to transfer RNA ; and (iii) Shamaila and co-workers showed that AuNPs may affect the bacterial respiratory chain by attacking nicotinamide **(Pedro *et al.*, 2018)**.

Metal Oxides

Metal oxides NPs are among if not the most important, foremost explored and studied family of NPs and are famous to effectively, rising as hopeful candidates to challenge antimicrobial resistance (Kadiyala ***et al.,*** 2018). Iron compound (Fe3O4), flowers of zinc (ZnO), and oxide (CuO) possess antimicrobial properties and may be applied in clinical care. Thanks to the intrinsic photocatalytic activity of the metal oxides they generate ROS and become powerful agents against bacterium These are delineate in additional detail on the subsequent sections **(Pedro *et al.*, 2018)**.

Iron oxide (FE3O4)

The synthesis of iron compound NPs could also be achieved via totally different routes. The medicine mechanism of those NPs is especially attributed to dissolved metal ions and also the generation of ROS **(Wang *et al.*, 2017)**. Super-paramagnetic iron compound Nanoparticle carry out intercellular movement by penetrating the membrane and officious with the negatron. it's been delineating that iron compound NPs will harm macromolecules, proteins, through the formation of ROS and together with DNA.

Method of synthesizing of Nanoparticles

Many techniques are used for the synthesis of Ag-NPs by exploitation of chemical, physical, chemistry, and biological ways (Figure 2). every technique has its advantages and disadvantages with common issues of value, measurability, uniform particle size, and also the size distribution **(Petra *et al.*, 2018)**. historically, metal nanoparticles are created by physical ways like particle sputtering or periodical optical maser ablation and chemical ways like reduction, thermal synthesis, sol-gel technique, hydrothermal and so on. However, recently, the environmentally friendly synthesis ways (by exploitation of natural products) are developed underneath the branch of "green syntheses." relying upon the chosen path of synthesis and totally different experimental conditions, the silver NPs of various morphology, sizes, and shapes are often obtained. Nevertheless, the foremost necessary criteria is that the size distribution that ought to be achieved narrow as possible for the target-specific applications. Three necessary ways (chemical, physical and biological) for the synthesis of nanoparticles are mentioned as follows **(Petra *et al.*, 2018)**.

Chemical methodology of synthesis

Among the present strategies, the chemical strategies are commonest used for the assembly of Ag-NPs. The chemical reduction of metal ions is that the most universal and simple route for the preparation of the metal nanoparticles **(Oliveira *et al.*, 2005)**. The chemical transformation of the silver ions into the silver nanostructures will occur by photochemical methodology, wet chemical synthesis with or while not templates, by using liquid, chemical compound templates, solution-based methodologies like aspartate reduction and starch-mediated reduction, etc. Generally, the chemical synthesis method of the Ag-NPs in answer typically employs 3 main elements which has metal precursors (for formation of AgNPs: AgNO three AgClO four, AgCl, (PPh three) 3AgNO 3, CF3CooAg), reducing agents and stabilizing/capping **(Iravani *et al.*, 2014)**.

Physical methodology of synthesis

In the physical synthesis method of Ag-NPs, usually, the physical energies (thermal, ac power, and arc discharge) are used to supply Ag-NPs with a slender size particle distribution. This approach can permit us to produce large quantities of Ag-NPs at once (Oliveira et al., 2005). Under the physical strategies, the metallic NPs are often typically contrived by evaporation-condensation method that would be administered during a tube chamber at gas pressure. The large area of tube chamber, consumption of enormous quantity of energy, raising the environmental temperature round the supply material and tons of your time for achieving thermal stability, these are among the few drawbacks of the strategy. Another physical methodology of synthesis of Ag-NPs may be a thermal decomposition methodology used to synthesize the powdered Ag-NPs. This means that the Ag-NPs were ready with a really slender size distribution for synthesizing the metal NPs and by evaporating the source beneath the flow of carrier gas, i.e., air. It had been reported that the mean diameter, the geometric variance, and also the total concentration of spherical NPs while not agglomeration will increase with the temperature of the surface of the heater (Oliveira et al., 2005).

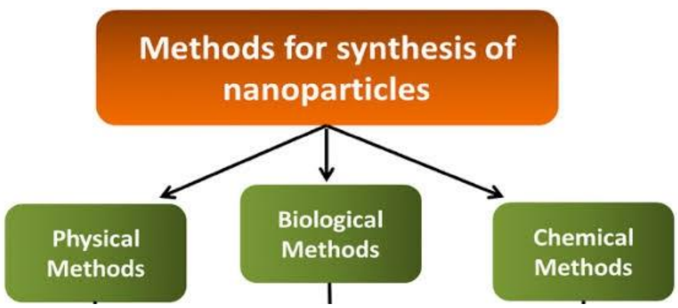

Figure 2 Methods for synthesis of Nanoparticles

Biological synthesis of nanoparticles

Usually, wet-chemical or physical methodology is employed to arrange the metal nanoparticles. However, the chemicals employed in physical and chemical strategies are typically costly, harmful and combustible however the biogenic strategies are a value effective, energy saver and having environmentally benign protocols technique for inexperienced synthesis of silver nanoparticles from completely different bacteria (yeast, fungi and bacterium, etc.) and plant tissues (leaves, fruit, latex, peel, flower, root, stem, etc.) **(Oliveira *et al.*, 2005)**. Phytochemicals (lipids, proteins, polyphenols, group acids, saponins, amino acids, polysaccharides amino polyose, enzymes, etc.) gift in plants are used as reducing and capping agent. The utilization of agro-waste and bacteria materials not solely reduces the value of synthesis however additionally minimizes the requirement of victimization venturous chemicals and stimulates inexperienced synthesis.

This methodology of synthesis is extremely easy, requiring less time and energy compared to the physical and chemical strategies with predictable mechanisms. The opposite blessings of biological methods is the supply of an enormous array of biological resources, attenuate time demand, high density, stability, and also the ready-to-soluble as-prepared nanoparticles in water. Therefore, biogenic synthesis of metal NPs unwraps up huge opportunities for the employment of perishable or waste materials.

Biosynthesis of silver nanoparticles by making use of bacteria

Several bacteria are documented to synthesize silver nanoparticles. Silver nanoparticles at 440 nm peak that corresponded to the surface plasmon resonance of silver nanoparticle were wont to extracellularly synthesize silver nanoparticles from nitrate solutions using *B. cereus*, *Bacillus subtilis*, *Staphylococcus aureus*, *E. coli*, *P. syringae* and *Streptococcus* species have been reported to produce silver nanoparticle **(Thu *et al.*, 2013)**.

Multidrug resistance (mdr) and nanoparticles

Multidrug-resistant (MDR) bacteria cause a significant threat to any or all fields of bioscience because it may result in treatment failure which might have severe consequences, especially in case of critical patients **(Wang *et al.*, 2017)**. The development of a new effective drugs is a complex process (**Ibisanmi and Aribisala, 2022**), at the moment a number of the foremost difficult Multidrug-resistant (MDR) organisms are *Pseudomonas aeruginosa*, methicillin-resistant *Staphylococcus aureus* (MRSA), extensively drug-resistant (XDR) *Mycobacterium tuberculosis*, *Escherichia coli*, *Acinetobacter baumannii* and *Klebsiella pneumonia*. Bacterial antibiotic resistance exhibited by completely different micro-organisms can be earned through numerous intrinsic or nonheritable mechanism **(Reidy *et al.*, 2013, Ibisanmi *et al.*, 2022)**. Intrinsic or 'natural' resistance is inherent to a bacterial species and involves inactivation of the antibiotic, cell permeability, the absence of the target or the presence of low-affinity targets and also the presence of effluence mechanisms. On the other hand, nonheritable mechanisms are genes embraced mutations in targeted by the transfer of resistance determinants borne on plasmids, the antibiotics, bacteriophages, transposons, and different mobile genetic materials. In general, this exchange is accomplished through the processes of conjugation (via plasmids) transduction (via bacteriophages), and conjugative transposons), and transformation (via incorporation into the body of body DNA, plasmids, and different DNAs from dying organisms). a really few novel antibiotics are discovered to treat these MDR organisms in past decades. Famous microbiologist Alexander Fleming said that "There is probably no chemotherapeutic drug to which in suitable circumstances the bacteria can not react by in some way acquiring fastness." Therefore, there is high probability that the organism may also become resistance to newly developed drugs at later stage, further these drugs are highly expensive. To the present finish nanoparticles are thought of to be sensible medicinal drug agents and should overcome the barrier of MDR because of their multifunctional mechanisms to intervene traditional cell practicality. Nanoparticles are shown to own the flexibility to anchor to the bacteria semipermeable membrane and afterwards penetrate it, thereby inflicting structural changes within the plasma membrane permeability resulting in necrobiosis. The most economical friendly is Silver NPs (SNPs), it also has antimicrobial property compared with others because of their extraordinarily massive area, that provides higher contact with bacteria. SNPs might target at the bacteria membrane, resulting in a dissipation of the nucleon driver that successively cause interference of organic process. Another mechanism concerned in microbicidal activity is that the generation of free radicals by the nanoparticles that have the flexibility to break the plasma membrane and create it porous which might ultimately result in necrobiosis. Metal nanoparticles have the affinity to act with sulfur and phosphorus containing biomaterials gift within the bacteria cell e.g., DNA bases. The metal nanoparticles will act on these soft bases and destroy the DNA which might result in necrobiosis. Nanoparticles are famed to modulate the bacteria signal transduction **(Singh *et al.*, 2016)**. The nanoparticles dephosphorylate the amide substrates on aminoalkanoic acid residues, that result in signal transduction inhibition and inhibition of bacteria growth. it's conjointly shown that there can be a unharness of silver ions from conductor nanoparticles and these ions will act with the thiol of the many very important enzymes and inflicting disruption of cellular functions, inactivate them. NPs conjointly exert their medicinal drug activities either by collapsing the membrane potential and inhibiting the nucleotidease activities to decrease the ATP level and also the different is by inhibiting the fractional monetary unit of organelle from binding to tRNA. many findings on antibacterial result of varied NPs and nanoconjugate systems are in short reviewed in preceding sections **(Petra *et al.*, 2018)**.

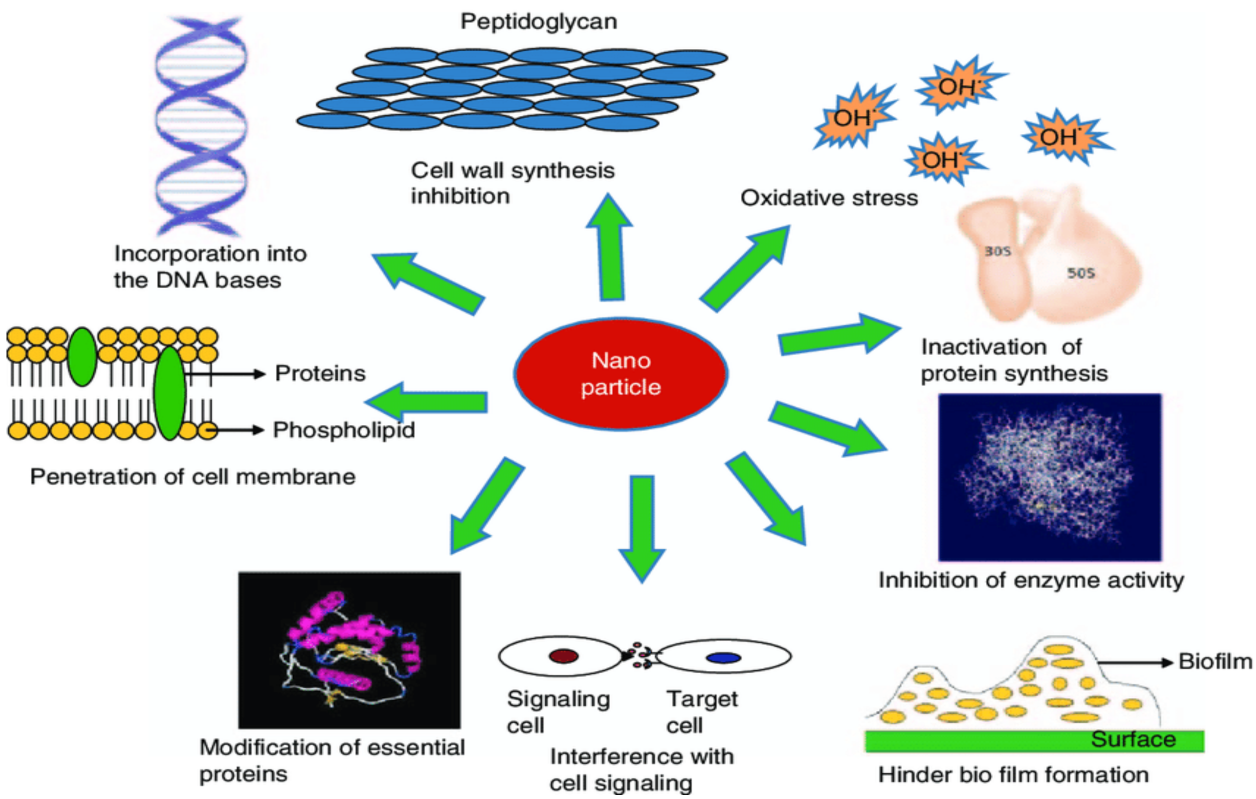

Figure 3 Graphical outline of various classes of nanosystems with illustration of their possible anti-biofilm mechanisms Nanosystems' role in overcoming antibiotic resistance

The emergence of aggressive bacteria together with the limited production of new antibacterial drugs has resulted in inefficiency of current antibiotic therapy with relevant risks on human health. The availability of new antibacterial agents appeared to be a very complex process in view of the capability to produce new effective and safe drugs, in addition to the high production costs and the time required for approval of new drugs that takes about 10–15 years **(Singh *et al.*, 2016; Natan *et al.*, 2017).** In 2016, several antibiotics were clinically tested for the market within the us of America **(Petra *et al.*, 2018)**. Sadly, however, within the last decades, linezolid was the sole approved antibiotic in conjunction with the recently discovered teixobactin **(Nermin *et al.*, 2020)**. Nanomedicine plays an important role in enhancing the effectiveness of existent medical drugs, by enhancing the chemical properties and stability of antibiotics, providing an opportunity of biofilm internalisation, prolongation of antibiotic unharness (Figure 3), additionally to the potential of targeted delivery to the location of infection and improved circulation with a resulting reduction of the connected facet effects compared to the corresponding free medicine **(Natan *et al.*, 2017)** .

Some Nanoparticles and their Bactericidals Action

Silver Nanoparticles

Among metal nanoparticles Ag-NPs are extensively studied and used as effective antimicrobial agents. The bactericidal impact of silver nanoparticles on micro-organisms is incredibly well known; but the bactericidal mechanism isn't fully understood. Studies showed that Ag-NPs attacks Gram negative bacteria by penetrating and anchoring the semipermeable membrane, and as a consequence, the leading structural amendment within the membrane morphology [Figure 4]. This led to vital increase in membrane porosity and alters transport through the cell membrane leading to death **(Singh *et al.*, 2016)**. it's conjointly been planned that the Ag-NPs powerfully move with thiol teams of important enzymes and phosphorus-containing

Action of Silver Nanoparticle on Microbes

There are numerous theories on the action of silver nanoparticles on microbes to cause the microbiocidal impact. Silver nanoparticles have the flexibility to anchor on the bacteria semipermeable membrane and after penetrate it, thereby inflicting structural changes on the cell wall like porosity of the cell wall and death of the bacteria cell. There's formation of peats on the cell surface moreover as accumulation of nanoparticles on the cell surface. The formation of free radicals on the bacteria cell surface by the silver nanoparticles perhaps thought-about as another mechanism by that death of the bacteria cell might occur **(Kim, J., 2007)** [Figure 4].

No Releasing Nanoparticles

Nitric-oxide-releasing NPs (NO NPs) also possess broad spectrum antibacterial activity which might inhibit the expansion of the many antibiotic resistant and sensitive bacterium like *K. pneumoniae, S. pyogenes, E. coli, E. faecalis and P. aeruginosa*. NO is a hydrophilic natural gas and lipophilic, and is unstable in an element surroundings. Reactions of NO with element or superoxide impromptu turn out reactive atomic number 7 and element intermediates that are cyanogenic to the cell and act as antimicrobial species **(Singh *et al.*, 2016)**.

Dinitrogen oxide and Dinitrosyl-Iron

complexes are generated. NO-associated macromolecule harm has been incontestable with peroxynitrite and gas (nitrogen dioxide). Peroxynitrite mediate macromolecule peroxidation of liposomes that contribute to the antimicrobial activities of NO **(Jones *et al.*, 2020)**. NO interactions with proteins involve reactive thiols, protoheme teams, iron-

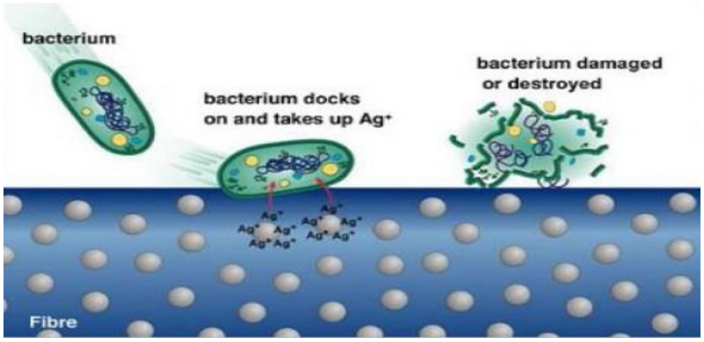

Figure 4 Silver nanoparticles destroyed bacteria cell

sulfur clusters, phenolic resin or aromatic organic compound residues, tyrosyl radicals, or amines **(Nermin *et al.*, 2020)**. Peroxynitrite and NO•2 conjointly nonspecifically oxidize proteins at a spread of websites.73 Studies of NO-related toxicity have incontestable inactivation of enzymes containing Fe-S clusters (e.g., aconitase, NADH dehydrogenase, succinate dehydrogenase) suggesting that NO• (NO radical) may directly unharness iron from metalloenzymes and cause iron depletion. The antimicrobial and healing efficaciousness of sustained unharness gas nanoparticles are investigated against methicillin-resistant SA (MRSA) and *Acinetobacter baumannii* using a murine wound and soft **(Singh *et al.*, 2016)**.

Metal compound Nanoparticles

Metal oxides nanoparticles (NPs) like TiO2, CuO and ZnO are proverbial to exhibit smart antibacterial properties **(Toolabi *et al.*, 2013)**. one among the common properties they share is their photocatalytic activity because of wide band gap. The photocatalytic activity is attributed to generation of reactive oxygen species (ROS). Copper (CuO) nanoparticles have shown activity against a variety of bacteria pathogens, as well as methicillin-resistant *staph aureus* (MRSA) and *Escherichia*, what is more, the power of CuO nanoparticles to cut back bacteria populations to zero was found to be increased within the presence of silver nanoparticles **(Kadiyala *et al.*, 2018)**.

CONCLUSIONS

he wide spread antibiotic resistance has put immense pressure on pharmaceutical industries to search new antimicrobial agents or modification of the existing drugs. In an area such as MDR, nanotechnology has potential to change the scenario and prevent the spread of drug resistance. Metallic nanoparticles of both biological and chemical origin are shown to be potential agents in antibacterial treatment. Nanoparticles not only demonstrated activity against MDR bacteria themselves, but also showed potential for the development of synergistic combinations that increases the antibacterial effect of existing antibiotics. They helped to revive the antibacterial activity of old generation antibiotics against which microbes have developed resistance. The review showcased the effect of various forms of radiations in combination with nanoparticles enhancing the antibacterial efficacy. Further work is still required in order to elucidate the entire mechanism of action of nanoparticles as bactericidal, toxicity of nanoparticles in human and better delivery of drug inside human system using nanodrug carriers. Nanoparticles coupled with either antibiotics and/or irradiation may provide a potential strategic remedy to combat MDR.
Further work is still required in order to elucidate the entire mechanism of action of nanoparticles as bactericidal, toxicity of nanoparticles in human and better delivery of drug inside human system using nanodrug carriers.

List of Abbreviations: MDR: Multidrug-resistant, XDR: extensively drug-resistant, NPs: Nanoparticles, MRSA: methicillin-resistant *Staphylococcus aureus*, ROS: reactive oxygen species, DNA: Deoxyribonucleic acid, VRE: vancomycin resistant enterococci, SNPs: Silver nanoparticles, ATP: Adenosine triphosphate**.**

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