IJASRM
International Journal of Advanced Scientific Research and Management, Volume 4 Issue 4, April 2019
www.ijasrm.com
ISSN 2455-6378

Nanoparticles: A Potential Nano Antibiotic

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Abstract

Nanotechnology is the science that deals with matter and can be described as working with nano size things i.e. 1-100nm. Nanoparticles and nanocomposite have great inhibitory, micro fungal, asthmatics and micro bacterial activities. The need of polymeric nanoparticles has been increased due to their multipurpose and comprehensive properties as carriers for inclusive drugs for therapeutic applications. Nanomaterials are not simply the next phase in making very small materials by using advance guard. They often require various manufacturing approaches. The massive area of surface and potential to self-assemble on a support surface assigned by nanoparticles simultaneously could be of use in all of these applications. Nanoparticles have distinctive applications as measured to other particles. Nanotechnology is anticipated to bring exhaustive changes in biological sciences such as diagnostics, drug delivery and manufacturing of bio–materials. Various types of nanoparticle products used in manufacturing and materials industries, magnetic pharmaceuticals, catalytic, cosmetics, energy and electronics. In this particular review Nanoparticles as Nanoantibiotics and their applications has been discussed.

Keywords: *Nanocomposite, Nanoantibiotics, Nanoparticles, Green Chemistry*

1. Introduction:

Nanotechnology is a field that is making an influence in the universe and mark in research field day by day. Nanotechnology is an area which has highly promising prospects for turning fundamental research into successful innovations [1-3]. It is also defined as a technique that mainly composed of the methods of segregation, unification and malformation of materials. While nanotechnology is observed to be beneficial in the future and is a technique that many people think will bring mostly positive response in every area [4]. Not only to raise the challenges of our production but in electronics, cosmetics, medicine, environment or various field to manufacture new products that will make positive changes in the lives of our citizens. It develops as antimicrobial agents and flow enthusiasm to the researchers due to the developing microbial resistances against metal ions, anti-toxins and the expansion of resistant strains. Nanoparticles as antimicrobial are increasingly used as an alternative to antibiotics. Due to the upliftment of development of nanotechnology, nanocomposite with different shapes and sizes have been prepared and used in some industries products and commodities. Nanoparticles have been studied for their different unique characteristics in order to hassle against micro-organisms [5-7]. Several traits in specific make nanoparticles inviolable in different fields. Foremost, Nanoparticles have a great ratio of surface area to volume, which raise contact zone with host. Further, they may be blended from metals, lipids, and polymers [8]. Furthermore, a multiple of chemical constitution, for example metal oxides and fullerenes, show a multiple range of chemical traits. The metals such as Silver, gold, Titanium, Magnesium, Selenium, Iron, Tin etc were known only as a metal till recently and it is only when the nano-era came into existence that researchers started to assume that these metals could also be manufactured at reinforced size. Metal nanoparticles were blend through an assemblage of techniques like cryochemical synthesis, electrochemical reduction, spark discharging and solution irradiation but the biogenesis of nanoparticles has spotlighted the hub of nanotechnology and biotechnologies in synthesing materials [9]. It remained unnoticed before the existence of nanotechnology that the Nanoparticles were being used by various organisms for bioremediation of different metals. The number of organism has been inured to clean environment by removing various reactive metals salts from the environment. For the biosorption of metals such as silver, cadmium and copper both the Gram positive and Gram negative metals have been used. Different microbes have been put on trial for their coherence of sorption of these metal ions and these then remained as a emulsion cluster mostly on the cell surface, periodically on the cytoplasm. Using microbes in synthesizes of metallic nanoparticles is very apathetic when compared with plant extracts.

The major advantages of using botanical extracts for union of metallic nanoparticles is that they are safe, non toxic and easily available [10]. Botanical extract is the most frequent product used for the manufacturing of metallic nanoparticles. The metallic nanoparticles prepared through different methods expected green synthesis are costly and also include the use of harmful chemicals, thus there is a need for an eco-friendly and economically conceivable way to synthesis these nanoparticles. The metallic nanoparticles can be synthesized by biological methods which are cost effective, ecofriendly, non toxic and easy to synthesize, is possible with help of fungi, bacteria, and botanical extracts. The nanosize of the particles played no remarkable role during medieval period. Metal nanoparticles reveal various characteristics which are else not found in bulk phases. It has been known that nanoparticles and its compounds have strong inhibitory and microbial activities for bacteria, virus and fungi. In today's era because of sudden appearance of contagious diseases caused by divergent pathogenic bacteria and development of antibiotic resistance companies and the researchers are observing for a new antimicrobial agent [11-12].

2. Classification of Nanoparticles on the basis of dimensions:

2.1 One dimension nanoparticles:

One dimensional system (thin film or manufactured surfaces) is in practice since decades. Thin films or monolayer is offering different technological properties, for example biological and chemical sensors, fiber-optic systems, magneto-optic and optical device, information storage systems and is common in the field of solar cells.

2.2Two dimension nanoparticles:

Carbon nanotubes

2.3 Three dimension nanoparticles:

Dendrimers, Fullerenes (Carbon 60), Quantum Dots (QDs)

3. Synthesis of Nanoparticles:

3.1 Bottom-up method

Bottom-up or constructive method is the method in which particles are starting from atoms/molecules are joint together/agglomerates in the which we can decide or fix the nanosize of particle. All the methods in which liquid or gaseous states are starting material are under this approach. Some methods like Sol-gel, spinning, chemical vapour deposition (CVD), pyrolysis and biosynthesis are the most commonly used [13].

3.2 Sol-gel.

The sol – a colloidal solution of solids suspended in a liquid phase. The gel – a solid Macromolecule submerged in a solvent. Sol-gel is type of bottom-up method and is mainly preferred due to its simplicity and as most of the nanoparticles can be produced from this method. It is a wet-chemical.technique that uses either a chemical solution or colloidal particles to an integrated network. Metal oxides and chlorides are the typically used precursors. It contains mainly four steps: hydrolyses, polymerization, growth of nanostructures, and agglomeration of atoms and ions take place. Various factors like temp, concentration of material, presence of catalyst, activating agent, nature of solvent, maixing\ stirring process affect the formation of nanoparticles. The prime requisite is for obtaining good quality in this method [14].

3.3Spinning : The process of spinning is carried out by a spinning disc reactor. It contains a rotating disc inside a chamber where the physical parameters such as temperature can be controlled. The reactor is generally filled with inert gases like nitrogen to remove oxygen inside and avoid chemical reactions. The disc is rotated at various speed where the liquid and water is pumped in. The spinning causes the atoms or molecules to fuse together and is precipitated, collected and dried. The characteristics nanoparticles synthesised from SDR is determined by various parameters such as liquid/precursor ratio, the liquid flow rate, disc surface, disc rotation speed, location of feed, , etc[15].

3.4Chemical Vapour Deposition (CVD): Chemical vapour deposition is the deposition method used to produce high quality, high performance, solid materials, typically under vacuum. The process is often used to produce thin films in industry like semiconductors industry. It is the formation of a non-volatile solid film on a substrate by the reaction of vapour phase chemicals that consist of the constituents required for the completion of the reaction. The reactant gases are introduced into a reaction chamber and are decomposed and reacted at a heated surface to form the thin film. The advantages of CVD are high purity, versatile, high density, generally quite conformal, economical in production. The disadvantages of CVD are the requirement of special equipment and the gaseous by-products are highly toxic [16].

ISSN 2455-6378

3.5Pyrolysis: The word Pyrolysis is coined from the Greek words pyro i.e. fire and lysis i.e. separating. Pyrolysis is the mostly used in heavily chemical industries for large scale production of nanoparticle. This phenomenon involves burning with flame. It is commonly used in the treatment of organic material. The precursor is either liquid or vapour that is fed into the furnace through a small hole at high pressure where it burn. The side product gases is then air classified to recover the nanoparticles. Some of the furnaces use laser and plasma instead of flame to produce high temperature for easy evaporation. The advantages of pyrolysis are simple, continuous process with high yield, efficient and cost effective [17].

3.6 Biosynthesis: Biosynthesis is a green and environmental friendly approach for the synthesis of nanoparticles that are nontoxic and biodegradable. Instead of using chemicals for capping purposes and bio reduction biosynthesis uses micro-organism like bacteria, fungi plant extracts etc. along with the precursors to produce nanoparticle. The biosynthesized nanoparticles has unique and enhanced properties that is used in biomedical application [18].

3.7 Top-down method: Top-down or destructive method is the technique in which microcrystalline size particles are fragmented into smaller size in the range 1-100 nm atleast in one dimension. All the methods in which solid states are taken involved in this category. Some of them are Mechanical milling, nanolithography, laser ablation, sputtering and thermal decomposition.

3.8Mechanical milling: Among the various top-down methods, mechanical milling is the most extensively used to produce various nanoparticles. The mechanical milling is used for milling and post annealing of nanoparticles during synthesis where different elements are milled in an inert atmosphere. The influencing factors in mechanical milling is plastic deformation that leads to particle shape, fracture leads to decrease in particle size and cold-welding leads to increase in particle size .

3.9Laser ablation: Laser Ablation Synthesis in Solution (LASiS) is a common method for Production of nanoparticles from different solvents. This is the fastest method for the preparation od nano-size particles. In this method high pulsed lazer beam is used for removal of atoms or molecules from the surface of target source. Lazer beam consist of high energy radiation when these radiations strike on targeted source (metal, metal oxide or ceramic).Atoms are removed from the surface of material in vapour state. The energy transferred is so high that it is more than the melting or boiling point of the material. Lazer beam are incident in a closed chamber in which are condensed on finger cooling tube (filled with N_2 at lower temperature) and with the help of this process nanoparticles are formed. As this method provide stable synthesis of nanoparticles in organic solvents and water that does not require any stabilizing agent or chemicals it is a 'green' process [19].

3.10Sputtering: In the case of Sputtering, evaporation of atom takes place by striking high energetic beam of inert gases and ions with source material as condition of inert environment is created atoms are ejected from the surface of target or source material. In this generally he gas is used for striking beam with the source other like Neon, Crypton etc. are also used but this is cheaper. In the evaporated state, the particles interact or colloid with the source particles and they decrease their energy and these particles in the nanoforms are condensed across the tube which is filled with N_2 gas. In this method, mixture od metal, non-metal, metal oxides can be converted simultaneously into nanoparticles. Rate of formation of nanoparticles is also very high but the drawback of this method is prone to contamination.

3.11 Thermal decomposition: Thermal decomposition is an endothermic chemical decomposition produced by heat that breaks the chemical bonds in the compound. The nanoparticles are produced by decomposing the metal by decomposing temperature i.e. the specific temperature at which an element chemically decomposes undergoing a chemical reaction producing secondary products.

3.12 Green Synthesis: Green chemistry may be defined as environment friendly chemical synthesis or the alternative synthetic pathway through which it reduces or eliminates the generation of hazardous substances. Green chemistry is totally based on the concept; Prevention is better than cure. Various techniques are available for the synthesis of nanoparticles like physical and chemical methods but keeping in mind the disadvantages of these methods like toxicity, costly and most important non-biodegradable researchers started synthesizing nanoparticles using green synthesis. Synthesis using bio-organisms is compatible with the green chemistry principles. "Green synthesis" of nanoparticles makes use of environmental friendly, non-toxic and safe reagents. Nanoparticles synthesized using biological techniques or green technology have diverse natures, with greater stability and appropriate dimensions since they are synthesized using a one-step procedure. Nanoparticles can be synthesized using a variety of methods including chemical, physical, biological, and hybrid techniques. Chemical and Physical methods have been using high radiation and highly concentrated reductants and stabilizing agents that are harmful for the environmental and to human health. Hence, biological synthesis of nanoparticles is a single step bio-reduction method and less energy is used to synthesize eco-friendly [20].

4. Properties of Nanoparticles:

Properties of nanoparticles are generally discussed under two sub headings:

4.1 Physical:

The physical properties include optical properties like the colour of the nanoparticle, UV absorption, its light penetration, and reflection capabilities, and reflection abilities in a solution or when coated onto a surface. It also includes the mechanical properties such as tensile strengths elastic, ductile and flexibility that play a significant factor in their application. Other properties like, settling characteristics, hydrophobicity, suspension, hydrophilicity, and diffusion are involved in one or the other things in this modern era. Magnetic and electrical properties such as semi conductivity, conductivity, and resistivity has led a path for the nanoparticles to be used in modern electronics thermal conductivity in renewable energy applications.

4.2Chemical:

The applications of chemical properties is determined by various factors such as the reactivity of the nanoparticles with the target and stability and Sensitivity to factors such as atmosphere, heat, moisture and light. The, anti-fungal, toxicity, disinfection and antibacterial properties of the nanoparticles are ideal for biomedical and environmental applications. Corrosive, anti-corrosive, oxidation, reduction and flammability characteristics of the nanoparticles determine their respective usage. The nanoparticle's synthesis produced from these chemical process is toxic for environment.

5. Characterization of Nanoparticles:

Characterization of nanoparticles is based on the size, morphology and surface charge, using such advanced microscopic techniques as transmission electron microscopy (TEM), atomic force microscopy (AFM) and scanning electron microscopy (SEM). Properties like in vivo distribution of the nanoparticles the average particle diameter, size distribution and charge affect the physical stability. Properties like shape, size and surface morphology are determined by electron microscopy techniques.

5.1Scanning Electron Microscopy (SEM):

SEM is an electron microscope that scans the area with a centralized beam of electrons and brings out images of a given sample. This technique determines the surface morphology, size and shape with direct reminisce of the nanoparticles. Therefore it offers various choices in sizing analysis and morphology. However SEM provides minimum information about the true population exemplar and size distribution. During the method of SEM characterization solution of nanoparticles should be initially convert into a dry powder. This powder form is then kept up on a sample holder and after that laminated with an electrical metal using a sputter coater is performed. When focused fines ray of electrons is bombarded further analyses of sample is carried out. Secondary electrons which are released from the sample surface determine the surface characterization of the sample. Polymer of the nanoparticles can be damaged by this electron beam. In addition these techniques frequently need corresponding information about size distribution, are time consuming and costly.

5.2Transmission Electron Microscope (TEM): This technique can anticipate diffraction, imaging and spectroscopic information, either simultaneously or in a serial manner, of the specimen with an atomic or a sub-nanometer spatial resolution. TEM operates on different principle than SEM i.e. it uses electrons instead of light, yet it often brings same type of data. The sample preparation for TEM is time consuming and complex because of its requirement to be ultra thin for the electron transmittance. TEMs find application in virology, cancer research and material sciences as well as semi conductor, pollution and semiconductor research. After dissemination they are secured using either a negative staining material. To facilitate handling and to make nanoparticles withstand against the instrument vacuum. Alternatively nanoparticles sample can also be exposing to liquid nitrogen temperatures after embedding in vitreous ice. When a beam of electrons is transmitted through an ultra thin sample it interacts with the sample as it passes through the surface characteristics of the sample are obtained.

6.Applications of Nanoparticles:

Nanoparticles are being utilized in various fields, or being assessed for use. The list below initiating few of the uses developing sparsely such as in medicine, manufacturing and material, in environment, energy and electronics etc.

6.1 Nanoparticle Applications in Medicine:

To furnish drugs to tumors nanoparticles of polymeric corpuscle nanoparticles are used. For ultra efficient treatment of chronic bacterial contagion clusters of bacteria are broken by polymer's use coated iron oxide nanoparticles. The potential of the nanoparticle to restorate immune responses is affected due to the surface change of protein embedded nanoparticles and may be used in respiratory vaccines. Oxygen free radicals are removed that are available in a patient's bloodstream following a traumatic abrasion with the help of cerium oxide nanoparticles which act as an antioxidant. Firstly, the nanoparticles blot up the oxygen free radicals followed by the release of oxygen in a harmless state, accrediting the nanoparticle to blot up more free radicals. Researchers are making headway by different methods to use carbon nanoparticles known as nanodiamonds in medical utilizations. For example, to expand bone growth nearby dental or joint implants nanodiamonds with protein molecules together can be used. To treat brain tumors researchers are experimenting the use of chemotherapy drugs affixed to nanodiamonds. To treat leukemia other researchers are evaluating the use of chemotherapy drugs clasped to nanodiamonds.

6.2 Nanoantibiotics : Despite the reality that we live in world of facilitate and intentive technologies for illuminating underlying mechanisms of diseases and molecularly designing new drugs, contagious diseases continue to be one of the major health problems worldwide. In order to fight super bug bacteria nanoparticles have been studied abundantly for their antimicrobial properties. Nanoantibiotics must be the major hub because of the increasing 'superbugs' resistant pathogen as one of the major clinical problems over worldwide [21]. Biological production of nanocrystals has found its greatest implementation mainly in drug delivery systems and towards medicine. The problem of drug-resistant bacteria in near future could possibly be overruled by highly-targeted nanoparticles that can be able to deliver higher doses of available antibiotics. Combination studies are being done between nanoparticles and antibiotics and it could improve the scheme of dosage based targeted therapy. This non-traditional ways also provides a very few options for plague to thrive resistance due to availability of various targets and different groups of nanoparticles. Several traits in specific make nanoparticles well fortified prospects as a traditional antibiotic drug alternative [22]. Firstly, contact area increases with host microbes because they have a large surface zone to volume ratio. Further, they may be blended from various types of metals, polymers and lipids. The size of the nanoparticles is the key to success against antibiotic resistant strains of bacteria. On the nano scale, particles can behave as molecules and easily probe the cell membrane by connecting with a cell and restrict in vital molecular route if the chemistry is feasible [23].

6.3 List of few metals used as Nanoantibiotics

(i) Silver Nanoparticles: Silver Nanoparticles have proved to be most efficacious due of its high antimicrobial efficacy against viruses, bacteria and other eukaryotic micro-organisms. They are undoubtedly the most widely used nanomaterials among all, thereby being used as water treatment, antimicrobial agents, sunscreen lotions, in textile industries etc.

(ii) Gold nanoparticles: Gold nanorods are used to detect beneficial for cancer diagnosis cancer stem cells, for identification of various classes of bacteria and in immunochemical studies for identification of protein interactions. They are used as lab tracer in DNA fingerprinting to diagnose presence of DNA in a sample. They are also used for detection of aminoglycoside antibiotics like gentamycin, neomycin and streptomycin.

(iii) Alloy: Alloy nanoparticles reveal structural properties that are dissimilar from their bulk samples. Since Ag has the highest electrical conductivity among metal filters and, unlikely many other metals, their oxides have relatively better conductivity, Ag flakes.

7. Conclusion:

Nanoparticles are the most attractive for commercialization applications. . Various techniques are available for the synthesis of nanoparticles like physical and chemical methods but keeping in mind the disadvantages of these methods like toxicity, costly and most important non-biodegradable researchers started synthesizing nanoparticles using green synthesis. In order to fight super bug bacteria nanoparticles have been studied abundantly for their antimicrobial properties. Nanoparticles obtained through these green synthesis are used as antibiotics. wide extent of nanoparticles has been used for electronic, antibiotics and biomedical products. In the given review, we provide a inclusive understanding of the nanoparticles synthesis methods like electrode position, sol-gel techniques, chemical precipitation, mechanical attrition has been briefly explained. The properties of the nanoparticles also described.

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