A Review on Nanoparticles: Synthesis, Types Characterization and Applications

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Abstract— Nanotechnology includes the production and utilization of materials which exist at the nanoscale, and ranges up to 100 nm size. It has the potential to replace a series of medical and biotechnological tools and procedures so that they are potable, cheaper, safer and easier to administer. Nanoparticles can synthesized chemically or biologically. Different types of nanoparticle platforms which are differentiated based on their size, shape, composition and their functionalities. Biological systems have ability to convert metal ions into metal nanoparticles. Nanoparticles can be used in drug and gene delivery, water treatment, biomolecules detection, medicine, Biosensors etc. Also nanoparticles have variety applications in day to day life.

Keywords: Nanoparticles, Synthesis, Types, Characterization, Applications

I. INTRODUCTION

Nanotechnology is an emerging field in science that involves study and application of very small things. Nanoparticles are smaller particles with size ranging from 1-100 nm, so due to their size may differ from bulk material.

Currently, different types of metallic nanomaterials have been synthesized using metals such as copper, zinc, titanium, alginate, gold, magnesium and silver. [1] Due to their relatively larger surface area, nanoparticles often exist with distinctive size dependent properties. Nanoparticles have many applications in the different fields like environment, energy and medical technologies because of their unique or improved properties which is primarily determined by size structure, composition along with their self-organized film structures. Current review focuses on nanoparticles synthesis, types, characterization and most advanced application related to nanotechnology.

Nanoparticles can be synthesized chemically or biologically. Many adverse effects have been associated with chemical synthesis methods due to presence of some toxic chemicals absorbed on the surface. [2] Eco friendly alternative for physical and chemical methods are biological method of synthesis of nanoparticles using microorganisms, and plants or plant extracts.

Ecofriendly methods for the synthesis of nanoparticles is carried out and leads to formation of an important branch of biotechnology specifically silver nanoparticles, which have variety of applications.

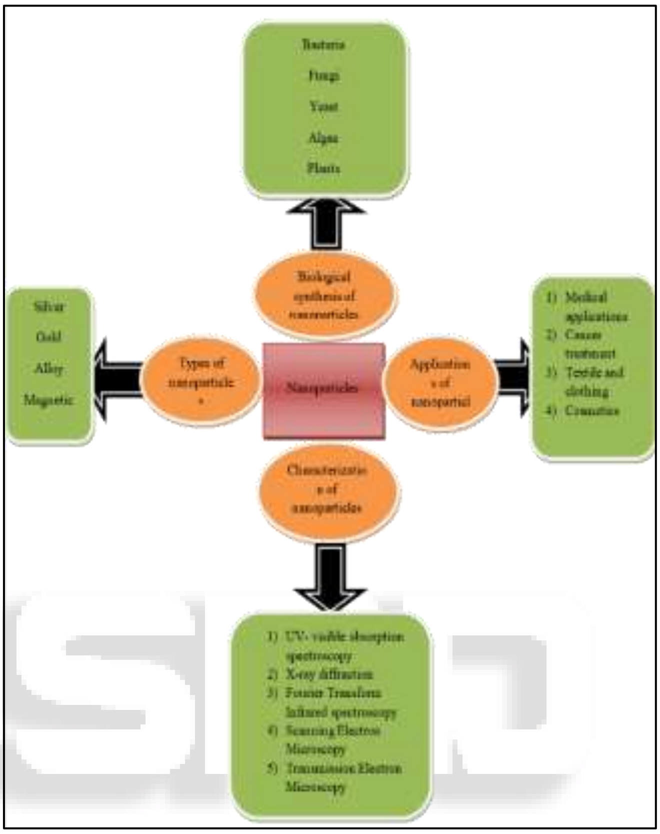

Fig. 1: Nanoparticles: Synthesis, types, Characterization and applications

II. NANOPARTICLES BIOSYNTHESIS MECHANISM

Biosynthesis of nanoparticles using microorganisms is a green and eco-friendly technology. Different Varieties of microorganisms both prokaryotes and eukaryotes used for biosynthesis of metal nanoparticles viz. silver, gold, platinum, zirconium, palladium, iron, cadmium and metal oxide etc. It includes microorganisms like bacteria, actinomycetes, fungi and algae. Nanoparticles can be synthesized by intracellularly or extracellularly depending on the location of nanoparticles.

Intracellular mechanism of biosynthesis of nanoparticles involves transportation of ions into microbial cells and formation of nanoparticles in the presence of enzymes. As compared to the size of intracellularly formed nanoparticles, the nanoparticles formed outside the organism are larger.[3] The size of nanoparticles is related to the nucleating particles inside the organism.

Nanoparticles produced extracellularly has more applications as compared to nanoparticles produced. Mostly fungi are known to produce nanoparticles extracellularly because fungi are involved in the production of enormous secretory components, which are involved in the reduction and capping of nanoparticles. Not all the organisms are found to be competent for the synthesis of nanoparticles. In case of silver nanoparticles, when organism contain silver resistant machinery, and concentration of silver ions is provided in limit organism produce silver nanoparticles.[2]

III. SYNTHESIS ROUTES OF NANOPARTICLES

Three routes involved in nanoparticles synthesis i.e. chemical route, physical route and biological route. Although nanoparticles fabrication using chemical route is quick process and results in formation of large number of nanoparticles but in this method many toxic chemicals are used for the stabilization and capping of nanoparticles which leads to the formation of non-ecofriendly environment.[4] Physical method is mostly expensive which involves complex experimental instrument for the nanoparticles fabrication. Furthermore, the nanoparticles produced from physical and chemical methods are not used in medicines. It was observed that many biological systems have the abilities of converting metal ions into metal nanoparticles by the reduction capacities of the proteins and metabolites present in these organisms. Nanoparticles Synthesis by biological methods are easy, cost-effective and environmental friendly.

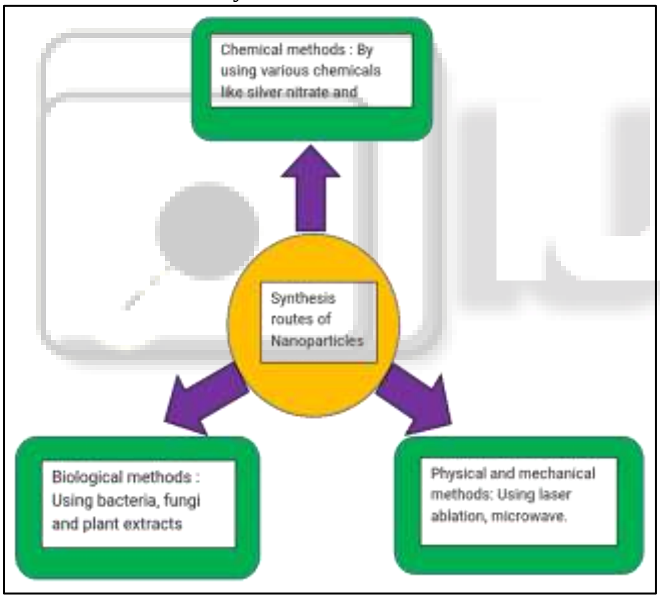

Fig 2: Different routes for synthesis of Nanoparticles.

IV. BIOLOGICAL ROUTE FOR THE SYNTHESIS OF NANOPARTICLES

A. *Synthesis of Nanoparticles:*

1) *Bacteria:*

Bacteria have incredible ability to reduce metal ions and hence they are best option for nanoparticle synthesis. Bacterial species used for synthesis of metallic nanoparticles are Acinetobacter sp., E. coli, Klebsiella pneumonia, Lactobacillus spp., Bacillus cereus, Pseudomonas sp. Bacillus licheniformis was used for synthesis of silver nanoparticles.[5] Culture supernatants of Klebsiella pneumoniae, Escherichia coli, Enterobacter cloacae showed rapid synthesis of nanoparticles. Rhodococcus sp. Showed intracellular production of gold nanoparticles [5] Pseudomonas fluorescence showed extracellular production of copper nanoparticles [6] Bacillus licheniformis showed extracellular production of silver nanoparticles [7] Geobacter sulfurreducens showed extracellular production of palladium nanoparticles [8] Lactobacillus sp. Showed extracellular production of titanium dioxide nanoparticles. [9]

2) *Fungi:*

Fungi are known to produce large amount of extracellular proteins that help in stability of nanoparticles. Fungi showes good biomass production and it also minimizes additional step require to extract filtrate. A. fumigates and Phoma sp. can be used for the biosynthesis of silver nanoparticles extracellularly. Fungus Cylindrocladium floridanum used for synthesis of gold nanoparticles [10]. Fusarium oxysporum used for extracellular synthesis of Au-Ag NPs[11] and also for Fe_3O_4 NPs [12]. It was noted that in 7 days, the fungi accumulated face-centered cubic [FCC] [111]-oriented crystalline gold nanoparticles on the surface of the mycelia, Uv- vis spectroscopy used for characterization of nanoparticles, absorption band was observed at 540nm. Aspergillus niger also used for synthesis of gold nanoparticles and nanoparticles synthesis were confirmed by absorption band which appeared at 530nm. Trichoderma viridae showed synthesis of polydispersed silver nanoparticles at 27^0 C. Characterization was done by UV- vis spectrum by looking for absorption band at 420nm. Magnetite, Fe3O4 magnetite nanoparticles are synthesized from Verticillium sp and Verticillium sp.

3) *Yeast:*

Yeast strains have more advantages over bacteria because they shows higher mass production of NPs and they easy to control in laboratory circumstances, also they synthesize numerous enzymes and shows rapid growth with the use of simple nutrients. Silver tolerant yeast strain MKY3, showed extracellular synthesis of hexagonal silver nanoparticles of size 2-5 nm [13] Yarrowia lipolytica cells were incubated with changed concentrations of chloroauric acid and formed cell-related gold NPs and nanoplates. Moreover, it is found out that the amount of cells and the concentrations of utilized salt can affect the size of nanoparticles. Candida glabrata showed both extra and intracellular synthesis of Cds nanoparticles. [14] Schizosaccharomyces pombe showed intracellular production of Cds nanoparticles.[15] Pichia jadinii showed intracellular production of Au nanoparticles. [16]

4) *Algae:*

Algae are great biological species to be used for synthesis of nanoparticles. Both live and dead biomass of algae is used for synthesis of nanoparticles. Synthesis of nanoparticles using algae is cost-effective and ecofriendly too. Large amount of reducing agents are present in algae which reduces metal salts to metal nanoparticles. Spirulina platensis used for extracellular synthesis of gold, silver, Au/Ag biometallic nanoparticles.[17] Tetraselmis kochinensis showed intracellular production of gold nanoparticles. [18]

5) *Plants:*

Nanoparticle synthesis using plants is simple, rapid, stable, ecofriendly and cost-effective method. Readily available plant materials are used for synthesis of nanoparticles. Root and leaf extract of medicinal herbal plant Panax ginseng used for synthesis of gold and silver nanoparticles. [19] Leaf extract of Euphorbia prostrate used for synthesis of silver and titanium dioxide nanoparticles. Leaf extract of Ginkgo biloba used for synthesis of copper nanoparticles. Root extract of Red ginseng used for synthesis of silver nanoparticles. Leaf extract of Azadirachta indica and Nigella sativa used for synthesis of silver nanoparticles. Leaf extract of Lawsonia inermis and Gardenia jasminoides used for synthesis of iron nanoparticles [20] Exact mechanism for synthesis of plant mediated nanoparticles is not clear. It is reported that proteins, vitamins, amino acids, organic acids and secondary metabolites such as flavonoids, terpenoids, alkaloids, polysaccharides played important role in metal reduction. Also they act as capping and stabilizing agents [20]

V. TYPES OF NANOPARTICLES

A. *Silver:*

Silver nanoparticles are of great importance because of their antimicrobial efficacy against bacteria, viruses and other organisms. They are most widely used nanoparticles among all. They are used as antimicrobial agents, in textile industries, for water treatment, sunscreen lotions etc. [21]

B. *Gold:*

Immunochemical studies for identification of protein interactions have been done using Gold nanoparticles [AuNPs]. They are also used for detection of many antibiotics like streptomycin, gentamycin and neomycin. Gold nanorods are used to detect cancer stem cells, beneficial for cancer diagnosis and for identification of different classes of bacteria [21]

C. *Alloy:*

Alloy nanoparticles have structural properties that are different from their bulk samples. Ag has the highest electrical conductivity, unlike many other metals, their oxides have relatively better conductivity, Ag flakes are most widely used. Bimetallic alloy nanoparticles shows more advantages over ordinary metallic NPs [21]

D. *Magnetic:*

Magnetic nanoparticles like Fe3O4 [magnetite] and Fe2O3 [maghemite] are also produced by biological method. They have been actively used for, sorting of stem cells, targeted cancer treatment [magnetic hyperthermia] and their manipulation, gene therapy, DNA analysis, guided drug delivery and magnetic resonance imaging [MRI] [21]

VI. CHARACTERIZATION OF NANOPARTICLES

A. *UV-Visible Absorption Spectroscopy:*

Absorbance spectroscopy is employed to work out the optical properties of an answer. during this light is suffered the sample solution and also the amount of absorbed light is measured. When the wavelength is varied and also the absorbance is measured at each wavelength. The absorbance will be accustomed measure the concentration of an answer by following Beer-Lamberts Law. The optical measurement of UV-visible spectrophotometer has different absorbance peak like 410nm when treated with the Nerium Obander plant extract after addition of aqueous 1mM nitrate solution [22] just in case of tree get synthesized with Iron nanoparticles by the indication of suitable surface Plasmon resonance with high band intensities and peaks was found through UV-visible spectroscopy at the range of 620nm.[22]

B. *X-ray Diffraction:*

For determination of crystallographic structure and morphology, X-ray diffraction technique is used. there's increase or decrease in intensity with the quantity of constituent. this system is employed to determine the metallic nature of particles gives information on translational symmetry size and shape of the building block from peak positions also provide information on electron density inside the building block, namely where the atoms are located from peak intensities [21].

C. *Fourier Transform Infrared [FTIR] Spectroscopy:*

It Measures infrared intensity vs. wavelength of sunshine. it's accustomed determine the character of associated functional groups and structure of biological extracts with nanoparticles. Structure and components of molecule are identified by infrared absorption bands. When IR radiation is more established a sample a number of infrared is absorbed by sample and a few of its is transmitted. Spectrum generated shows the molecular absorption and transmission and creates molecular fingerprint of sample [23]

D. *SEM and TEM:*

SEM and TEM mostly used for morphological studies of nanoparticles. These techniques were utilized by many researchers to point out whether the synthesized nanoparticles are more or less in size.

E. *Scanning Electron Microscopy:*

The characterization of Scanning microscope analysis is used to see the dimensions, shape & morphologies of formed nanoparticle SEM gives high resolution images of the surface of a sample is desired. The scanning microscope works as same principle as an optical microscope, but it measures the electrons scattered from the sample instead of photon. Because electrons will be accelerated by an electrical potential, the wavelength are often made shorter than the one in all photons. thanks to this SEM capable of magnifying images up to 200.000 times [23]

F. *Transmission Electron Microscopy [TEM]:*

In Transmission electron microscopy technique a beam of electrons directly transmitted through an ultra-thin specimen that beam then interacts with the specimen because it passes through specimen. Production of a picture takes place from the interaction of the electrons transmitted through the specimen; the image is then magnified and focused onto an imaging device, sort of a fluorescent screen, on a layer of photographic material, or to be detected by a sensor like a CCD camera. In both physical and biological sciences TEM forms a significant analysis method. [23] TEMs shows applications in various fields such as in cancer research, virology, materials science yet as pollution, nanotechnology and semiconductor research.

VII. APPLICATIONS OF NANOTECHNOLOGY

A. Medicinal Applications of Nanoparticles:

They are utilized in Fluorescent biological labels, drug and gene de-livery. [24] they're used for the bio detection of pathogens and for the detection of proteins. Nanoparticles are often intended for the probing of DNA structure and tissue engineering. Nanoparticles is mainly used for destruction of tumor with the help of heating [hyperthermia].They help in separation and refinement of cells and molecules also phagokinetic studies. Other applications with reference to manufacturing and materials, energy and electronics are: Iron nanoparticles are accustomed close up dissolving agent trash in water. Iron oxide nanoparticles are useful in cleaning of arsenic from water wells. Platinum-cobalt nanoparticles catalyst is employed in cell [25] Copper nanoparticles are more reliable to use in space mission and other high stress environment. the facility of battery are often increased by coating of silicon nanoparticles over anodes of lithium ion batteries. Semiconductors nanoparticles is employed in a coffee temperature writing that's accustomed produce low cost solar cells.

B. Applications of Nanoparticles in Cancer Treatment:

Currently cancer therapies are limited to surgery, radiation and chemotherapy. But these methods can cause damage to normal tissuesor it should cause incomplete eradication of the cancer. Specifically Polylactic-co-glycolic acid [PLGA] nanoparticles used in the systems of drug delivery for various therapeutic agents like chemotherapy, antibiotics, antiseptic, antioxidant drugs and are favorable in tumor or DNA- targeting.[26] Needle shaped PLGA NPs more cross endothelial cell membranes very efficiently and deliver siRNA into cellular cytoplasm. Needle shaped PLGA NPs also induce considerable cytotoxicity. In lysosome needle shaped PLGA NPs causes damage to lysosomal membrane and by apoptosis signaling pathways they induce cell apoptosis [26]

C. Nanoparticles in Textiles and Clothing

From last years, Nanotechnology based progress in textile laments, yarns, and fabric finishing was used for the event of latest and enhanced textile products. Newly, a nano-based technology developed by Swiss company Scholler for producing brand of materials called soft-shells, which could be a functional stretch multi-layer fabric. [27] Furthermore, several antimicrobial textile treatments are presently being fashioned which will play very noteworthy characters in fortification againsta wide selection of physical/chemical/biological terrorizations. Nano-based composite textile materials develops other gifted sector, which is leading the advances of novel materials for engineering applications. Nanofibres, surface nano roughen fibres, nanoparticles, nanoporous materials, quantum dots these nanomaterials are utilized in textiles. Metal oxides and ceramics nanoparticles are employed in textile finishing [27]

D. Nanoparticles in Cosmetics

Nanoparticles are found to be useful in several cosmetics products like conditioners, make up, suntan lotion and hair care products. Cosmetics are applied to the horny layer, called dead cells, which is employed to shield the body from the in-filtration of foreign materials including cosmetics. To extend the concentration of active agents in cosmetics liposomes [vitamin A, E and CoQ10] are used]. Sunscreens contain insoluble, mineral based materials. Mineral UV filters present in sunscreen protect consumers from harmful effects of UV exposure [28]

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