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"A REVIEW ON NANOPARITICLES:TYPES, SYNTHESIS AND APPLICATIONS"

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Abstract:

The recent past in the technological development evidenced that evolution in Nanotechnology and nanoscience is the key factor. Nanotechnology is multidisciplinary science which deals with physics, chemistry, materials science and other engineering sciences. The applications of Nanotechnology are spreading inalmost all the branches of science and technology. Nanoparticles (NPs) are widely employed in different research areas, ranging from analytical chemistry and environmental science to medicine, the agriculture and pharmaceutical industry. Nanotechnology plays a big part in our modern daily lives, ranging from the biomedical sector to the energy sector. There are different physicochemical and biological methods to synthesise nanoparticles towards multiple applications. Generally nanoparticles size ranges from 1 to 100 nm with one (or) more dimensions. Generally nanoparticles classified into inorganic, organic and particles based on carbon in nanometric scale that has properties improved compared to larger size of respective materials. They show properties which are enhanced such as strength, sensitivity, high reactivity, stability, surface area etc., due to their smaller size. They were synthesized by various methods for research and commercial uses which are classified into three types- chemical, physical and mechanical processes which had sawn a vast improvement. We have prepared this paper to present a review on nanoparticles, their types, characterization, synthesis methods and applications in field of environment.

Keywords: Nanoparticles, Nanoscience, types, synthesis, characteristics and applications.

1.I. NTRODUCTION:

The field of nanomedicine has seen significant progress in the past decades, both in design and the scope of applications. Various techniques are used to characterize nanoparticles (NPs) and predict their ultimate fates in human body. Cutting-edge properties of NPs such as; nature, biocompatibility, anti-inflammatory and antibacterial activity, effective drug delivery, bioactivity, bioavailability, tumor targeting, and bio-absorption have led to a growth in the biotechnological, and appliedmicrobiological applications of NPs. Nanoparticles are spherical, polymeric particles composed of natural or artificial polymers. Nanoparticles are the fundamental components of Nano technology. Nano particles size ranges from 1 to 100nm which are made up of metal, metal oxides, organic matter, carbon. Nanoparticles differ from various dimensions, to shapes and sizes apart from their material.Surface can be irregular with surface variations or a uniform. Among nanoparticles some are crystalline or amorphous with single or multi-crystal solids either agglomerated or loose.In the process of synthesizing new drugs, most drug candidates are insoluble or poorly soluble in water which causes a huge downfall for the pharmaceutical industry.One of the main reasons for a drug‟s insolubility is its complex and large molecular structure. It has been reported that over 65% of new active pharmaceutical ingredients(APIs) are either poorly soluble in water or insoluble. Due to their low aqueous solubility properties and high permeability, they are categorized as class II of the Biopharmaceutics Classification System (BCS), where the dissolution step is the rate limiting factor in drug absorption. NPs are also defined as zero dimensional nanomaterials distinguishing them from one and two-dimensional nanomaterials that have either one or two dimensions larger than nanoscale respectively. They are differentiated from their bulk counterparts in terms of size, chemical reactivity, mobility, energy absorption etc.The pharmaceutical industries are now facing a challenge to improve the dissolution characteristic of poorly watersoluble drugs which is the key factor in enhancing drug bioavailability.However, chemical and physical methods are expensive and harmful but biological method is simple, non-toxic, rapid and eco- friendly. For instance, they help to increase the stability of drugs/proteins and possess useful controlled release properties. This review predominately focused on synthesis of different types of nanoparticles using chemical, physical and biological methods. The major goals in designing nanoparticles as a delivery system are to control particle size, surface properties and release of pharmacologically active agents in order to achieve the site-specific action of the drug at the therapeutically optimal rate and dose regimen. Cutting-edge properties of NPs such as; nature, biocompatibility, anti-inflammatory and antibacterial activity, effective drug delivery, bioactivity, bioavailability, tumor targeting, and bio-absorption have led to a growth in the biotechnological, and applied microbiological applications of NPs.Nanoparticle technology is rapidly advancing, providing novel and effective treatments for various diseases (Emerich & Thanos, 2003), including neurodegenerative diseases, such as Alzheimer’s and Parkinson’s diseases. It also explains about the characteristics of nanoparticles and concluded with various applications.

2. Classification of Nanoparticles:

NPs are broadly divided into various categories depending on their morphology, size and chemical properties.The nanoparticles are generally classified into the organic, inorganic and carbon based.

2.1 Organic nanoparticles:

Organic nanoparticles/nanobeads are of major interest in the material and life sciences.Their small size provides them with unique properties putting them at the forefront of emerging technologies. They are highly useful in bioanalysis and basic science as model systems to study single molecule behavior, molecular recognition, signal transduction, and protein-mediated membrane fusion processes once functionalized/associated with biological entities (such as DNA or antibodies) as catalytic interfaces, for sensor applications, for drug delivery, as well as other applications. Micelles, Dendrimers, ferritin and liposomes etc. are commonly known polymers or organic nanoparticles. These nanoparticles are non-toxic, biodegradable, and some particles such as liposomes and micelles have a hollow core also known as nano capsules and are sensitive to thermal and electromagnetic radiation such as heat and light.Organic nanoparticles already play an important role in many biotechnology applications and promise to take center stage for many new and emerging applications in the coming years. Interesting future developments include not only biomedical applications such as improved delivery of drugs to tumor cells and the use of dendrimers for regenerative medicine but also fields such as water purification and disinfection, food production, and packaging.

2.2 Inorganic nanoparticles:

Inorganic nanoparticles can be obtained either by division of large chunks of material (the top-down approach) or by integration of individual atoms and molecules into wider nanostructures (the bottom-up approach). Inorganic nanoparticles are non-toxic,hydrophilic, biocompatible and highly stable compared to organic materials. Drug delivery systems designed for enhanced drug efficacy and reduced adverse effects have evolved accompanied by the development of novel materials. Biomedical applications of nanotechnology are mainly suited for diagnostic techniques, nano drugs and delivery systems, and biomedical implants.Inorganic nanoparticles are particles which are not made up of carbon. Metal and metal oxide-based nanoparticlesare generally categorized as inorganic nanoparticles.

a. **Metal NPs:** Metal NPs are purely made of the metals precursors. The commonly used metals for nanoparticle synthesis are aluminium (Al), cadmium (Cd), cobalt (Co), copper (Cu), gold (Au), iron (Fe), lead (Pb), silver (Ag) and zinc (Zn).These nanoparticles can be synthesized by chemical, electrochemical, or photochemical methods. In chemical methods, the metal nanoparticles are obtained by reducing the metal-ion precursors in solution by chemical reducing agents. These have the ability to adsorb small molecules and have high surface energy. Due to well-known localized surface plasmon resonance (LSPR) characteristics, these NPs possess unique optoelectrical properties.The starting materials of the metal nanomaterials are divalent and trivalent metal ions. There are different methods for the preparation of metal nanoparticles like chemical or photochemical methods. By using reducing agents the metal ions are reduced to the metal nanoparticles. These have a high surface area and have the good adsorption ability of small molecules. They are widely used in different research areas, environmental and bio imaging studies. Not only a single nanoparticle but also the mixing of two or more nanoparticles with the size control can also be achieved. By doping different metals even the rare earth metals can change the main element characteristics. By doping different elements in different constitutions their properties also get vary.Metal nanoparticles are one of the earliest nano-additives used in diesel modification, which mainly includes metal monomers and metal oxides. Metal nanoparticles have a high energy density, strong catalytic effect, high ignition probability, super-plasticity andlow sintering temperature, which facilitate the combustion of fuels. Due to their advanced optical properties, metal NPs find applications in many research areas. Gold NPs coating is widely used for the sampling of SEM, to enhance theelectronic stream, which helps in obtaining high quality SEM images.

b. **Ceramic NPs:** Ceramic nanoparticles (CNs) are emerging as drug delivery vehicles, mainly due to the small size (<50 nm) and physicochemical properties, and include particles made from albumin, iron oxide, or silica. Ceramic NPs are predominantly composed of oxides, carbides, phosphates,and carbonates of metals and metalloids such as calcium, titanium, silicon, etc. Most of ceramic NPs consist of silica or alumina. The porous nature of NPs contributes to them physical shield from degradation and degranulation. Nanophase ceramics can be divided into NPs, nanoscaffolds, and nanoclays. Ceramics NPs are inorganic nonmetallic solids, synthesized via heat and successive cooling. They can be found in polycrystalline, dense, amorphous, polycrystalline, dense, porous or hollow forms. Therefore, these NPs are getting great attention of researchers due to their use in applications such as catalysis, photocatalysis, photodegradation of dyes. By controlling some physical properties, these nanoparticles can be formulated in drug delivery system especially in targeting tumors, glaucoma, and some bacterial infections.

c. **Semiconductor NPs:** Semiconductor materials possess properties between metals and nonmetals and therefore they found various applications in the literature due to this property.Semiconductor nanoparticles or quantum dots (QDs)have shown excellent applications in labeling of DNA, cells, and proteins. They offer tunable emission spectra that can be 271 tuned throughout the ultraviolet, visible, near-infrared, and mid-infrared spectral ranges [43]. Moreover, they have high photo stability as well as resistance against photo bleaching, and manipulatable surface features.They include compounds of elements in groups II–VI,II–V, and IV–VI within the periodic table, some examples of nanostructured semiconductor materials are GaN, GaP, InP; InAs belong to group III–V; ZnO, ZnS, CdS, CdSe, CdTe belong to group II–VI; and semiconductors silicon and germanium belong to group IV. They are used in photocatalysis, electronics devices, photo-optics and water splitting applications. Semiconductor materials possess properties between metals and nonmetals and therefore they found various applications in the literature due to this property.

d. **Polymeric NPs:** Polymeric NPs are solid colloidal particles of size range 10 nm–1 μm. They are generally made of biodegradable and biocompatible polymers. They are used as drug carriers by encapsulating or entrapping the drugs. The drugs can adsorb over the surface physically or chemically. They are excellent carriers because of small size, water-solubility, non toxicity, high shelf life, and excellent stability. These are normally organic based NPs and in literature a special term polymer nanoparticle (PNP) is collectively used for it. Depending up on the preparation these are nanospheres or nano-capsular shaped. The former are matrix particles whose overall mass is generally solid and the other molecules are adsorbed at the outer boundary of the spherical surface. In thelatter case the solid mass is encapsulated within the particle completely. The PNPs are readily functionalized and thus find bundles of applications in the literature.Some of the merits of polymeric nanoparticles are controlled release, protection of drug molecules, ability to combine therapy and imaging, specific targeting and many more. They have applications in drug delivery and diagnostics.The drug deliveries with polymeric nanoparticles are highly biodegradable and biocompatible.Polymeric nanoparticles can also be made from synthetic polymers. Synthetic polymers can be of two types: biodegradable and nonbiodegradable. Poly(d,l-lactic-co-glycolic acid) (PLGA) is a biodegradable polymer and PLGA has been used for the transdermal delivery of indomethacin, Spantide II, and ketoprofen.

Polyacrylates are nonbiodegradable polymers that have been used for dermal and transdermal delivery of drugs but to a lesser extentcompared to biodegradable polymers.

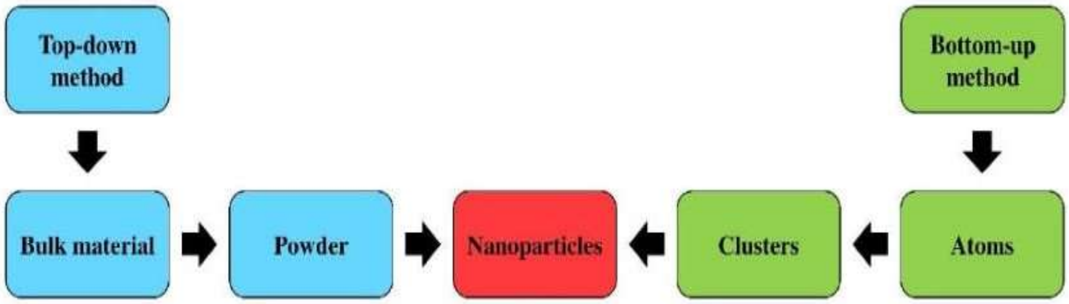
e. **Lipid-based NPs:** These NPs contain lipid moieties and effectively using in many biomedical applications.Lipid-based nanoparticles (LNPs) are a highly adaptable class of nanocarriers that have gained widespread usage in medical research and pharmacology. LNPs offer several benefits, such as safeguarding drugs from *in vivo* degradation, boosting their solubility and efficacy, enabling targeted drug delivery to the disease site, regulating drug release, and altering drug biodistribution. Generally, a lipid NP is characteristically spherical with diameter ranging from 10 to 1000 nm. Like polymeric NPs, lipid NPs possess a solid core made of lipid and a matrix contains soluble lipophilic molecules. Surfactants or emulsifiers stabilized the external core of these NPs.These nanoparticles have application in the biomedical field as a drug carrier and delivery and RNA release in cancer therapy.

2.3. Carbon-based NPs:

The main constituent in this type of nanomaterials is the carbon. Carbon nanotubesand fullerenes are related to this type. Basically, the CNTs are embedded with graphene sheets which are rolled into a tube. These are much stronger than steel and can be useful for structural enhancement. The CNTs are of a singlewalled type and multi-walled type. Fullerenes are the hollow cage structure particles with sixty or more carbon atoms. These are allotropes of carbon. Its structure similar to hollow football with pentagonal and hexagonal carbon units is organized in a regular pattern. They show good electrical conductivity, electron affinity, and high strength.Carbon- based nanoparticles include two main materials, namely, carbon nanotubes (CNTs) and fullerenes. CNTs are nothing but graphene sheets rolled into a tube. These materials are mainly used for the structural reinforcement as they are 100 times stronger than steel. CNTs can be classified into singlewalled carbon nanotubes (SWCNTs) and multi-walled carbon nanotubes (MWCNTs). CNTs are unique in a way as they are thermally conductive along the length and non-conductive across the tube. Fullerenes are the allotropes of carbon having a structure of hollow cage of sixtyor more carbon atoms. The structure of C-60 is called Buckminsterfullerene, andlooks like a hollow football. The carbon units in these structures have a pentagonal and hexagonal arrangement.These have commercial applications due to their electricalconductivity, structure, high strength, and electron affinity. The rolled sheets can be single, double or many walls and therefore they are named as single-walled (SWNTs),double-walled (DWNTs) or multi-walled carbon nanotubes (MWNTs), respectively. They are widely synthesized by deposition of carbon precursors especially the atomic carbons, vaporized from graphite by laser or by electric arc on to metal particles. Lately, they have been synthesized via chemical vapor deposition (CVD) technique. Due to their unique physical, chemical and mechanical characteristics, these materials are not only used in pristine form but also in nano-composites for many commercial applications such as fillers, efficient gas adsorbents for environmental remediation and as support medium for different inorganic and organic catalysts.

3. Synthesis of Nanoparticles:

The nanoparticles are synthesized by various methods that are categorized into bottom-up or top-down method. A simplified representation of the process is presented in synthesis process.



3.1. Bottom-up method:

Bottom-up approaches of production of nanomaterials comprise the miniaturization ofmaterials constituents to the atomic level with the additional procedure leading to the development of nanostructures. Throughout the further progression, the physical forces working at nanoscale combined simple units into larger stable structures. The methodology is principally based on the principle of molecular recognition (self- assembly). Self-assembly means growing more and more things about one's kind fromthemselves. Many of these techniques are still under development or are just beginning to be used for the commercial production of nanoparticles.

- **Sol-gel:** The sol–gel method is a wet-chemical technique that is extensively used for the development of nanomaterials. This method is used for the development of various kinds of high-quality metal-oxide-based nanomaterials. This method is called a sol–gel method as during the synthesis of the metal-oxide nanoparticles, the liquid precursor is transformed to a sol, and the sol is ultimately converted into a network structure that is called a gel. The sol – a colloidal solution of solidssuspended in a liquid phase. The gel – a solid macromolecule submerged in a solvent. Sol-gel is the most preferred bottom-up method due to its simplicity and as most of the nanoparticles can be synthesised from this method. It is a wet- chemical process containing a chemical solution acting as a precursor for an integrated system of discrete particles. Metal oxides and chlorides are the typically used precursors in sol-gel process.
- **Spinning:**The synthesis of nanoparticles by spinning is carried out by a spinning disc reactor (SDR). It contains a rotating disc inside a chamber/reactor where the physical parameters such as temperature can be controlled. The reactor is generally filled with nitrogen or other inert gases to remove oxygen inside and avoid chemical reactions. The disc is rotated at different speeds where the liquid i.e., precursor and water are pumped in. The spinning causes the atoms or molecules to fuse together and is precipitated, collected and dried10 . The variousoperating parameters such as the liquid flow rate, disc rotation speed,liquid/precursor ratio, location of feed, disc surface, etc. determines the characteristics nanoparticles synthesized from SDR.
- **Chemical Vapor Deposition:** Chemical vapour deposition is the deposition of a thin film of gaseous reactants onto a substrate.Precursors are deemed appropriate for CVD if they exhibit sufficient volatility, high chemical purity, strong evaporation stability, cheap cost, a non-hazardous nature, and long shelf life. The deposition is carried out in a reaction chamber at ambient temperature by combining

gas molecules. A chemical reaction occurs when a heated substrate comes in contact with the combined gas.This reaction produces a thin film of product on the substrate surface that is recovered and used. Substrate temperature is the influencing factor in CVD. The advantages of CVD are highly pure, uniform, hard and strong nanoparticles. The disadvantages of CVD are the requirement of special equipment and the gaseous by-products are highly toxic.

- **Pyrolysis:** Pyrolysis is the most commonly used process in industries for large- scale production of nanoparticle. It involves burning a precursor with flame.The precursor is either liquid or vapour that is fed into the furnace at high pressure through a small hole where it burns. The combustion or by-product gases are thenair classified to recover the nanoparticles. Some of the furnaces use laser instead of flame to produce high temperature for easy evaporation. The advantages of pyrolysis are simple, efficient, cost effective and continuous process with high yield.
- **Biological synthesis of Nanoparticles:** Biosynthesis is a green and environmental friendly approach for the synthesis of nanoparticles that are nontoxic and biodegradable.Biosynthesis uses bacteria, plant extracts, fungi, etc. along with the precursors to produce nanoparticle instead of convention chemicals for bioreduction and capping purposes. The biosynthesized nanoparticles has unique and enhanced properties that finds its way in biomedicalapplications.The synthesis of nanoparticles by biological synthesis carried by the following methods:

- **Synthesis by plant extract:** The synthesis by plant extract is free from toxicity and the plants tender the superior option for the synthesis of nanoparticles.Plant extracts are used to obtain metallic nanoparticles, but recent research has demonstrated an effective and unique method for obtaining nanoparticles via well-managed purified plant components. The gold and silver nanoparticles canbe produced from the plant extracts like Geranium, aloe vera, sun dried cinnamoncamphora, azadiracta indica etc.
- **Synthesis by bacteria:** Multicellular and single-cellular organisms are used to produce materials that might be intracellular or extracellular. The bacterial enzymes occur through an intracellular signaling mechanism for the conversion of ions into NPs. The synthesis of NPs in previous years has enlarged comprehensively due to its immense applications. Bacillus species are widely used in the production of metal nanoparticles, since this bacterium has ability to fabricate extracellularly. The size ranges from 10 to 20 nm. Gold nanoparticles can also be produced.
- **Synthesis by fungi:** Fungi have some advantages over other microbial methods of obtaining nanoparticles in that it is easy to develop media, scale-up formationis easier, downstream reactions are easier, an increased number of proteins are generated, and biomass is simple to prepare. However, fungal enzymes increase the number of nanoparticles synthesized and have achieved the reductive properties required for the production of stable nanoparticles. The nanoparticles can be produced by using various species of fungi like aspergillus niger, aspergillus orizae, fusarium solani. Phoma globerta has been traced to produce silver nanoparticles and its efficacy against E.coli, S.aureus, P.aeruginosa has been assessed.
- **Synthesis by yeast:** This uses candida glabarta and schizosaccharomyce pombe for the synthesis of cadmium nanoparticles. The silver and gold nanoparticles are also investigated using extremophilic

yeast strain isolated from the acid mine drainage. The marine yeast rodosporidium diobovatum has been explored for the synthesis of stable lead sulphide nanoparticles.

- **Synthesis by biological particles:** The biological particles like proteins, peptides,virus, enzymes are used as biological particles in the synthesis of nanoparticles.

Tobacco mosaic virus helps in the mineralization of sulphides. Cowpea chlorotic mottle virus, cowpea mosaic virus have also been employed and these can be demonstrated on the surface of M13 bacteriophage.

3.2.Top-down methods:

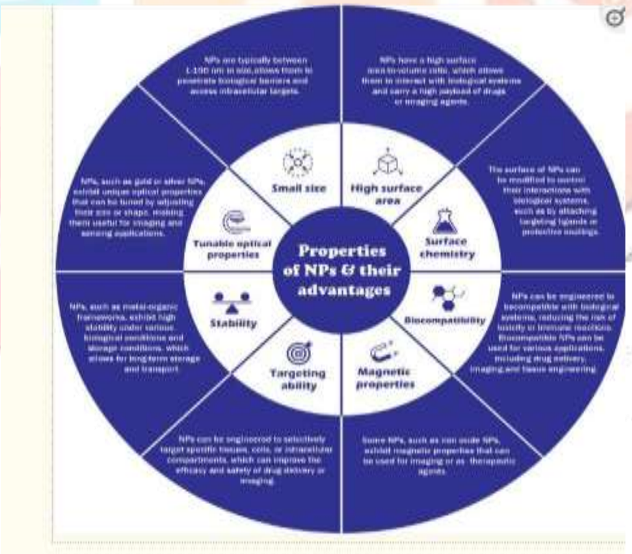
Bulk materials are fragmented in top-down methods to create nano-structured materials. Top-down or destructive method is the reduction of a bulk material to nanometric scale particles. Mechanical milling, nanolithography, laser ablation, sputtering and thermal decomposition are some of the most widely used nanoparticle synthesis methods.

- **Mechanical milling:** The mechanical milling process uses balls inside containers and may be carried out in various mills, typically planetary and shaker mills, which is an impact process with high energy. Among the various top-downmethods, 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.
- **Nanolithography:** The use of directed assembly for nanolithography has received much attention for organizing materials on the nanoscale into ordered structures and producing complex structures with small feature sizes. Nanolithography is the study of fabricating nanometric scale structures with a minimum of one dimension in the size range of 1 to 100 nm. There are various nanolithographic processes for instance optical, electron-beam, multiphoton, nanoimprint and scanning probe lithography. Generally, lithography is the process of printing a required shape or structure on a light sensitive material that selectively removes a portion of material to create the desired shape and structure. The main advantage of nanolithography is to produce from a single nanoparticle to a cluster with desired shape and size. The disadvantages are the requirement of complex equipment and the cost associated.
- **Laser ablation:** A microfeature can be made by employing a laser beam to vaporize a single material. Laser ablation synthesis produces nanoparticles by striking the target material with an intense laser beam. Laser Ablation Synthesis in Solution (LASiS) is a common method for nanoparticle production from various solvents. The irradiation of a metal submerged in a liquid solution by a laser beam condenses a plasma plume that produces nanoparticles.It is a reliable top-down method that provides an alternative solution to conventional chemical reduction of metals to synthesis metal-based nanoparticles. As LASiS provides a stable synthesis of nanoparticles in organic solvents and water that does not require any stabilizing agent or chemicals, it is a "green" process.
- **Sputtering:** In the sputtering deposition process, energetic gaseous ions bombardthe target surface, causing the physical ejection of small atom clusters depending upon the incident gaseous-ion energy.

Sputtering is a process used to produce nanomaterials via bombarding solid surfaces with high-energy particles such as plasma or gas. Sputtering is considered to be an effective method for producing thin films of nanomaterials. The sputtering process can be performed in different ways, such as utilizing magnetron, radio-frequency diode, and DC diode sputtering. In general, sputtering is performed in an evacuated chamber, to which the sputtering gas is introduced. A high voltage is applied to the cathode targetand free electrons collide with the gas to produce gas ions. The positively chargedions strongly accelerate in the electric field towards the cathode target, which these ions continuously hit, resulting in the ejection of atoms from the surface of the target. Sputtering is the deposition of nanoparticles on a surface by ejecting particles from it by colliding with ions.Sputtering is usually a deposition of thin layer of nanoparticles followed by annealing. The thickness of the layer, temperature and duration of annealing, substrate type, etc. determines the shape and size of the nanoparticles.

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

4.Application of Nanoparticles:



NPs, due to their above-mentioned unique or enhanced physicochemical properties, are used in a wide range of applications in different fields. In addition, severalpotential applications are in research and development. Here we present some examples of these applications.

4.1.Therapeutic applications of Polymeric nanoparticles:

- The usage of polymeric nanoparticles as drug carriers for the treatment of many disease entities opens encouraging possibilities in clinical application.
- They develop innovative drug delivery system in the treatment of neurodegenerative and brain associated diseases.

- Polymeric NPs provide protection to the drugs via encapsulating, entrapping them inside the core, conjugating, or adsorbing them on to the particle surface.
- Polymeric NPs deliver cargo-loaded molecules across the BBB by following endocytosis and transcytosis pathways.
- This polymeric coating is thought to reduce immunogenicity, and limit the phagocytosis of nanoparticles by the reticulo-endothelial system, resulting inincreased blood levels of drug in organs such as the brain, intestines, and kidneys.
- These have been applied in gene therapy to breast cancer cells, resulting in anti-proliferative effects.

4.2. Therapeutic applications of lipid based nanoparticles:

- These are mainly used to various types of cancer like GIT cancer, lung cancer,breast cancer, pancreatic cancer, prostate cancer.
- It significantly enhances transdermal penetration of phytomedicines inside skin.
- SLNs increase the therapeutic potential of eugenol and efficiently inhibited thegrowth of Candida infection during oral candidiasis.
- It has enhanced antimicrobial activity.

4.3. Therapeutic applications of semiconductor nanoparticles:

- It has significant attention in research and applications in emerging technologies such as nanoelectronics, nanophotonics, energy conversion, nonlinear optics, miniaturized sensors and imaging devices, solar cells, catalysis, detectors, photography biomedicine etc.

4.4.Therapeutic applications of ceramic nanoparticles:

- Ceramic nanoparticles like titania have also been added into polymer matrices to adjust composite surface chemistry, topography, and wettability (surface energetics) of the polymer matrix, aiming at the promotion of osteogenic responses on the material surfaces.
- Functionalized magnesium oxide, zirconia, sulfate, and calcium carbonate are added to polymethylmethacrylate (PMMA) bone cement to reduce the exothermic effect of PMMA while increasing its cytocompatibility, X-ray radiopacity, as well as antibacterial potential.
- Antibacterial effects of $BaSO_4$ nanoparticles against Staphylococcus aureus and Pseudomonas aeruginosa have been discovered, suggesting their potential applications as anti-infective additives to bone cement, implant coating, and medical tubing. Therefore, these NPs are used by researchers across the globe in wide applications, such as catalysis, photocatalysis, photo degradation of dyes, and imaging applications. Medical technologies use nanoceramics for bone repair.
- Ceramic NPs are also used in energy supply and storage, communication,transportation systems, construction, and medical technology.
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construction, and medical technology.

4.5. Therapeutic applications of carbon based nanoparticles :

- **Drug and gene delivery:** The application as drug delivery is very common in carbon-based nanoparticles, especially, the graphene-based nanoparticles. The π conjugated structure of six-atom rings of carbon can be conceptually consideredas a planar aromatic macromolecule. This unique structure offers a large loading capability to a variety of fluorescent probes and drugs. The chemical modification of graphene can allow the conjugation with targeting ligands, therefore, achieve the targeted delivery of the drug. Both in vitro and in vivo studies have provided the evidence of the graphene for delivering anti-cancer drugs to the desiredlocation of tumor cells, rather than the normal and healthy cells.
- **Bioimaging:** Carbon-based materials have long been investigated in many imaging applications. For example, fluorescence imaging (FL), two-photon FL, Raman imaging, magnetic resonance imaging (MRI), tomography (CT), photoacoustic imaging (PAI), computed positron emission tomography/single photon emission computed tomography (PET/SPECT), and multimodal imaging. Recently, a new form of carbonbased nanomaterials, carbon quantum dots, has attracted tremendous interests in its bioimaging applications.
- **Energy sources:** Carbon-based nanomaterials have been widely investigated as the catalysts and key components of hydrogen storage systems. Due to their intrinsic characteristics, carbon-based materials are a desired material as electrodes in capacitors and batteries. CNTs have shown a high reversible capacity for use in lithiumion batteries and also in a variety of fuel cell components. The high electrical conductivity also allows the CNT be used in current collectors and gas diffusion layers. The high surface area and thermal conductivity make CNT and graphene very useful as electrode catalyst supportsin fuel cells.

4.6. General applications of organic nanoparticles:

- **Liposomes:** Liposomes have been used as a potential drug carrier instead of conventional dosage forms because of their unique advantages which include ability to protect drugs from degradation, target to the site of action and reducethe noxiousness and other side effects. However developmental work on liposome drugs has been restricted due to inherent health issues such as squat encapsulation efficiency, rapid water leakage in the commodity of blood components and very poor storage, and stability. On the other hand, polymeric NPs promise some critical advantages over these materials i.e. liposomes. For instance, NPs help to increase the ratability of drugs or problems and possess convenient controlled drug release properties. They are also more resistant to low pH and bile salts that would be encountered in the gastrointestinal tract.
- **Dendrimers:** Dendrimers are widely used in the biomedical field where they are used as analogs to proteins, enzymes, and viruses where they are primarily used to focus the target cells and conjugated to the host dendrimeric cells, for example,poly(amidoamine) dendrimer. Dendrimers are extensively used in magnetic resonance to improve the contrasts of the image. For example, metallic dendrimers are used to create the magnetic resonance imaging contrast agent. Dendrimers are also used to mimic the variety of biomolecules and create the microenvironment.

4.7. Therapeutic applications of metallic nanoparticles:

- **As anti-Infective Agents:** Metallic nanoparticles have been described as a HIV preventative therapeutic. In a couple of studies, it has been shown that as virucidal agent silver acts directly on the virus by binding to the glycoprotein gp120. This binding in turn prevents the CD4 dependent virion binding which effectively decreases HIV1"s infectivity.and it has also been reported that metallic nanoparticles have been effective antiviral agents against herpes simplex virus, influenza, respiratory syncytial viruses.
- **In Multiple Myeloma:** Researchers have designed a nanoparticle based therapy that is effective in treating mice with multiple myeloma. Multiple myeloma is a cancer that affects plasma cells.
- **In Leukaemia**: B-chronic Lymphocytic Leukaemia (CLL) is an incurable disease predominantly characterized by apoptosis resistance, by co-culture with an anti- VEGF antibody, found induction of more apoptosis in CCL B cells. In CLL therapy, gold nanoparticles were used to increase the efficacy of these agents. Gold nanoparticles were chosen based on their biocompatibility, very high surface area, surface functionalization and ease of characterization. To the gold nanoparticles, VEGF antibodies were attached and determined their ability to kill CLL B cells.
- **In Rheumatoid Arthritis:** Scientists from the University of Wollongong (Australia) have built a new class of anti-arthritic drug which could be used by gold nanoparticles and it has fewer side effects. Rheumatoid arthritis is an autoimmune disease that occurs when the immune system does not function properly and attacks a patient"s joints. New research has shown that gold particles can invade macrophages, and stop them from producing inflammation without killing them. In the Journal of inorganic biochemistry it has been published that by reducing the size of gold into smaller nanoparticles (50 nm), it was able to cause more gold to immune cells with lesser toxicity.
- **In Photo Thermal Therapy:** Gold nanoparticles absorb light strongly as they convert photon energy into heat quickly and efficiently. Photo-thermal therapy (PTT) is an invasive therapy in which photon energy is converted into heat to kill cancer. In Radiotherapy Tumours are loaded with gold, this absorbs more X-rays as gold is an excellent absorber of X-rays.

4.8. Nanoparticles for gene delivery:

Polynucleotide vaccines work by delivering genes encoding relevant antigens to host cells where they are expressed, producing the antigenic protein within the vicinity of professional antigen presenting cells to initiate immune response. Such vaccines produce both humoral and cellmediated immunity because intracellular production of protein, as opposed to extracellular deposition, stimulates both arms of the immune system. The key ingredient of polynucleotide vaccines, DNA, can be produced cheaply and has much better storage and handling properties than the ingredients of the majority of proteinbased vaccines. Nanoparticles loaded with plasmid DNA could also serve as an efficient sustained release gene delivery system due to their rapid escape from the degradative endo-lysosomal compartment to the cytoplasmic compartment.This gene delivery strategy could be applied to facilitate bone healing by using PLGA nanoparticles containing therapeutic genes such as bone morphogenicproteins.

4.9. Nanoparticles for drug delivery into the brain:

The blood-brain barrier (BBB) is the most important factor limiting the development of new drugs for the central nervous system. The BBB is characterized by relatively impermeable endothelial cells with tight junctions, enzymatic activity and activeefflux transport systems. It effectively prevents the passage of water-soluble molecules from the blood circulation into the CNS, and can also reduce the brain concentration of lipid-soluble molecules by the function of enzymes or efflux pumps.Consequently, the BBB only permits selective transport of molecules that are essential for brain function.

4.10. Nanoparticles in food products:

Amorphous silica nanoparticles are used as anti-caking agent to maintain the flow properties in powder products (e.g., instant soups) and to thicken pastes. The conventional form of amorphous silica is known as food additive E551. It is also used in cosmetics, especially in sunscreens. Sunscreens contain titanium dioxide and zinc oxide nanoparticles, because they are colorless and reflect/scatter ultraviolet lightmore efficiently than larger particles. For example, from the first report on the use of titanium dioxide nanoparticles in a dye-sensitized solar cell it took more than 20 yearsto develop a commercially available product.

CONCLUSION

Nanoscience and nanotechnology are inherently transdisciplinary felds of science.Nanotechnology is improving our everyday lives by enhancing the performance and efficiency of everyday objects. It provides a clean environment by providing safer air and water, and clean renewable energy for a sustainable future.Theforegoing discussion shows that nanoparticulate systems have great potentials, being able to convert poorly soluble, poorly absorbed and labile biologically active substance into promising deliverable drugs. The core of this system can enclose a variety of drugs, enzymes, genes and is characterized by a long circulation time due tothe hydrophilic shell which prevents recognition by the reticular-endothelial system. To optimize this drug delivery system, greater understanding of the different mechanisms of biological interactions, and particle engineering, is still required. Further advances are needed in order to turn the concept of nanoparticle technology into a realistic practical application as the next generation of drug delivery system.

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