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# NANOPARTICLES: A COMPLETE REVIEW

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## ABSTRACT

This review is provided a detailed overview of the synthesis, properties, application and toxicities of nanoparticles exist in different forms. The word nanoparticles come from the Greek word nanus which means dwarf or very small. Nanoparticles (NPs) are the novel invention of modem science in which drug is surrounded by a polymeric membrane where the drugs are dissolved, entrapped, adsorbed, attached and/or encapsulated into or onto a Nano-particulate matrix. They can be classified into different classes based on their properties, shape, nanoparticles have unique physical and chemical properties due to their high surface area and nanoscale size. The development of Nanotechnologies is important in terms of diagnosis, treatment, and prevention of disease. Nanoparticles can be prepared by using the various methods such as Emulsion-Solvent Evaporation Method, Double Emulsion and Evaporation Method, Salting Out Method, Emulsions Diffusion Method, Solvent Displacement/Precipitation method, Polymerization method and Coacervation or ionic gelation method.

**KEYWORDS:** Nanoparticles*, Modern Drug Delivery, Preparation, Characterization, Applications.

## INTRODUCTION

Nanotechnology is termed as design, production, characterization and applications of structures, systems and devices by controlling shape and size at nanometer scale.

Nanoparticles (NPs) are defined as solid particles or particulate dispersion drug carriers that may or may not be biodegradable. The drug is entrapped, dissolved encapsulated or attached to a nanoparticle matrix. The term nanoparticle can be used for both nanospheres and nanocapsules.[1]

The nanoparticles (NPs) are prepared by using biodegradable and biocompatible polymers in size range between 10-1000 nm where the drug is entrapped, dissolved, encapsulated or attached to a nanoparticle matrix. The field of polymer nanoparticles (NPs) is gaining its prominence and expanding quickly and playing vital role in a wide spectrum of areas ranging from photonics, electronics, conducting materials, medicine, sensors biotechnology, environmental technology and pollution control. NPs are promising vehicles for drug delivery by easy manipulation to prepare carriers with the objective of delivering the drugs to targeted site. Polymer- based nanoparticles effectively carry drugs, DNA and proteins to target cells and organs. Their nanometer-size faciliitate effective permeation through cell membranes and stability in the blood stream.[2-6]

**ADVANTAGES**

- After parenteral administration to achieve both passive and active drug targeting particle size and surface characteristics of nanoparticles can be easily manipulated.
- To achieve high drug therapeutic efficacy and less side effects, during the transportation they control and sustain release of the drug and at the site oflocalization, altering distribution of the drug and subsequent clearance of the drug.
- By attaching targeting ligands to surface of particles or use of magnetic guidance site-specific targeting can be achieved.
- Includingoral, intra-ocular, parenteral and nasal, the system can be used for various routes of administration.
- Within the body, drug delivery to tiny areas can be achieved better by nanoparticles.
- Engineering enables researchers to exercise precisely on this scale and previously control over the biomaterials and physical features of polymers.
- Nanoparticles provide efficient delivery of drug to various parts of the body by overcoming the resistance offered by the physiological barriers in the body which is directly affected by particle size.
- Nanoparticles can aid in efficient drug delivery by improving aqueous solubility of poorly soluble drugs and increase bioavailability for organizedrelease of drug molecules, and

accurate drugtargeting.

- For targeted drug delivery, the surface properties of nanoparticles can be altered for proteins, small molecules, peptides, and nucleicacids loaded nanoparticles are not recognized by immune system and targeted to particular tissue types efficiently.
- By targeting nano drug carriersdrug toxicity can be reduced and more efficient drug distribution can be provided.
- Over various anatomic extremities of bodysuch as blood brain barrier (BBB) nano carriers holds potential to deliver biotech drugs

## 1.2. CLASSIFICATION OF NANOPARTICLES

There are various approaches for classification of nanomaterials. Nanoparticles are classified based on one, two and three dimensions.[7]

### 1.2 One dimension nanoparticles

One dimensional system, such as thin film or manufactured surfaces, has been used for decades in electronics, chemistry and engineering. Production of thin films (sizes1-100 nm) or monolayer is now common place in the field of solar cells or catalysis. These thin films are using in different technological applications, including information storage systems, chemical and biological sensors, fibre-optic systems, magneto-optic and optical device.

### 1) Two dimension nanoparticles

### a) Carbon nanotubes (CNTs)

Carbon nanotubes are hexagonal network of carbon atoms, 1 nm in diameter and 100 nm in length, as a layer of graphite rolled up into cylinder. CNTs are of two types, singlewalled carbon nanotubes (SWCNTs) and multi-walled carbon nanotubes (MWCNTs) .The small dimensions of carbon nanotubes, combined with their remarkable physical, mechanical and electrical properties, make them unique materials.[8] They display metallic or semi conductive properties, depending on how the carbon leaf is wound on itself. The current density that nanotubes can carry is extremely high and can reach one billion amperes per square meter making it a superconductor. The mechanical strength of carbon nanotubes is sixty times greater than the best steels. Carbon nanotubes have a great capacity for molecular absorption and offering a three dimensional configuration. Moreover, they are chemically and chemically very stable.

### 2) Three dimension nanoparticles

#### a) Fullerenes (Carbon 60)

Fullerenes are spherical cages containing from 28 to more than 100 carbon atoms, contain C60. This is a hollow ball composed of interconnected carbon pentagons and hexagons, resembling a soccer ball. Fullerenes are class of materials displaying unique physical properties. They can be subjected to extreme pressure and regain their original shape when the pressure is released. These molecules do not combine with each other, thus giving them Major potential for application as lubricants. They have interesting electrical properties and it has been suggested to use them in the electronic field, ranging from data storage to production of solar cells. Fullerenes are offering potential application in the rich area of nano electronics. Since fullerenes are empty structures with dimensions similar to several biological active molecules, they can be filled with different substances and find potential medical application.

#### b) Dendrimers

Dendrimers represents a new class of controlled-structure polymers with nanometric dimensions. Dendrimers used in drug delivery and imaging are usually 10 to 100 nm in diameter with multiple functional groups on their surface, rendering them ideal carriers for targeted drug delivery. The structure and function of dendrimers has been well studied. Contemporary dendrimers can be highly specialized, encapsulating functional molecules (i.e., therapeutic or diagnostic agents) inside their core[9] They are considered to be basic elements for large-scale synthesis of organic and inorganic nanostructures with dimensions of 1 to 100 nm They are compatible with organic structure such as DNA and can also be fabricated to metallic nanostructure and nanotubes or to possess an encapsulation capacity [10]Dendrimers have different reactive surface groupings (nanostructure) and compatible with organic structure such as DNA so their prolific use is particularly in the medical and biomedical fields. The pharmaceutical applications of dendrimers include nonsteroidal anti-inflammatory formulations, antimicrobial and antiviral drugs, anticancer agents, pro-drugs, and screening agents for high-throughput drug discovery.[11] Dendrimers may be toxic because of their ability to disrupt cell membranes as a result of a positive charge on their surface.

#### c) Quantum Dots (QDs)

Quantum dots are small devices that contain a tiny droplet of free electrons.QDs are colloidal semiconductor nanocrystals ranging from 2 to 10 nm in diameter. QDs can be synthesized from various types of semiconductor materials via colloidal synthesis or electrochemistry. The most commonly used QDs are cadmium selenide (CdSe), cadmium telluride (CdTe), indium phosphide (InP), and indium arsenide (InAs). Quantum dots can have anything from a single electron to a collection of several thousands. The size, shape and number of electrons can be precisely controlled. They have been developed in a form of semiconductors, insulators, metals, magnetic materials or metallic oxides. It can be used for optical and optoelectronic devices, quantum computing, and information storage. Colour coded quantum dots are used for fast DNA Testing. Quantum ots (QDs) refer to the quantum confinement of electrons and hole carriers at dimensions smaller than the Bohr radiuos. QD nanocrystals are generally composed of atoms from groups II and VI (that is CdSe, CdS, and CdTe) or II and V (such as In P) at their core. A shell (that is ZnS and CdS) can be further introduce to prevent the surface quenching of excitons in the emissive core and hence increase the photo stability and quantum yield of emission (Goldberg M et al., 2007). QDs also provide enough surface area to attach therapeutic agents for simultaneous drug delivery and in vivo imaging, as well as for tissue engineering.[12]

## 1.3 TYPES OF NANOPARTICLES

**Silver:** These are proved to be most effective because of their good antimicrobial efficacy against bacteria, viruses and other eukaryotic microorganisms[13-14] Among all the nanomaterials they are most widely used as antimicrobial agents, for sunscreen lotions, water treatment and in textile industries etc[15-16] By using the plants i.e.*Capsicum annuum*, *Azadirachta indica* and *Carica papaya* the successful biosynthesis of silver nanoparticles have been reported.[17-19]

**Gold:** For identification of protein interactions in immunochemical studies gold nanoparticles (AuNPs) are used. In DNA fingerprinting they are used as lab tracer to detect existence of DNA in a sample. Aminoglycoside antibiotics i.e. streptomycin, gentamycin and neomycin are also detected by using these nanoparticles. Detection of cancer stem cells, diagnosis of cancer and identification of different classes of bacteriadone by using Gold nano rods.[20-21]

**Alloy:** From the bulk samples, structural properties of alloy nanoparticles are different [22]Silver flakes are most commonly used due totheir highestelectrical conductivity among other metal fillers, their oxides also have relatively greater conductivity. By both metals and over ordinary metallic NPs bimetallic alloy nanoparticles properties are influenced whichshow moreadvantages.

**Magnetic:** Magnetic nanoparticles are known to be biocompatible i.e.maghemite and magnetite. For magnetic resonance imaging (MRI), guided drug delivery, targeted cancer treatment (magnetic hyperthermia), gene therapy, stem cell sorting and manipulation and for DNA analysis they have been actively considered.[23]

### 1.4 Preparation of nanoparticles

For the preparation of nanoparticles, the selection of the appropriate method is based on the drug to be loaded and physicochemical properties of the polymer. The primary preparation methods of nanoparticles includes:

**1. Emulsion-Solvent Evaporation Method**

The nanoparticles are mostly prepared by using this method. Two steps are mainly involved in this method. In an aqueous phase, emulsification of the polymer solution required in the first step. While in the second step, evaporation of polymer solution occurs and nanospheres are formed by inducing the polymer precipitation. Collection of nanoparticles is done by ultracentrifugation and to remove free drug or residue, washed with distilled water and for storage these are lyophilized.[24] This method is also known as solvent evaporation method an highpressure emulsification This technique involves homogenization under high pressure and overall stirring to remove organic solvent.[25] By adjusting the stirring rate, viscosity of organic and aqueous phases, temperature, type and amount of dispersing agent the size can be controlled.[26] However to lipid soluble drugs, this technique can be applied and by the scale up issues limitation are imposed. Polymers used are PLA[27], Poly (β- hydroxybutyrate) (PHB), Poly (caprolactone) (PCL), PLGA[28], cellulose acetate phthalate, and EC in this method.[29-32]

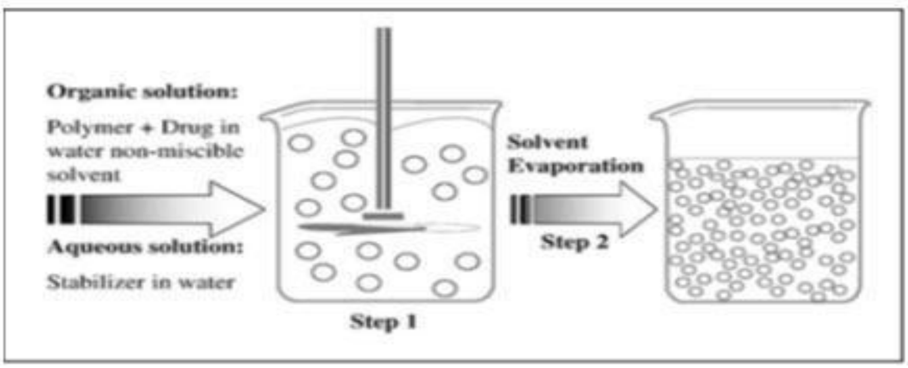


**Fig. 1: Representing a solvent emulsion Method.**

### 2. Double Emulsion and Evaporation Method

Poor entrapment of hydrophilic drugs is the main drawback of this method. Therefore to encapsulate hydrophilic drug the double emulsion technique is engaged, inwhich aqueous drug solutions is added to organic polymer solution with vigorous stirringto form w/o emulsions. With continuous stirring to form mixed emulsion (w/o/w), this w/o emulsion is added into another aqueous phase. Then by the evaporation solvent is removed and by centrifugation at high speed nano particles can be isolated. Before lyophilisation the prepared nanoparticles must be washed.[33] The variables used in this method are;incorporated quantity of hydrophilic drug, the amount of polymer, the volume of aqueous phase andthe stabilizer concentration. The characterization of nano particles also affected by these variables.[34]

### 3. Salting Out Method

By using salting-out from aqueous solution the water-miscible solvent is separated using this method.[35] Initially in a solvent, polymer and drug are dissolved which is consequently containing the saltingout agent (electrolytes, such as calcium chloride and magnesium chloride or sucrose as non- electrolytes) and polyvinylpyrrolidone(PVP) or hydroxyethylcellulose a is a colloidal stabilizer into an aqueous gel areemulsified. This oil in water emulsion is diluted with water or with an aqueous phase to increase the diffusion of solvent, which indicates the formation of nanospheres. Several parameters such as electrolyte concentration, concentration of polymers in the organic phase, type of stabilizer, stirring rate, internal/external phase ratio can be varied. This techni que leads to high efficiency and easily scaled up in the preparation of Ethyl cellulose, PLA and Poly(methacrylic) acids nanospheres.[36-37] Salting out may be useful for heat sensitive substances because an increase of temperature does not require in this technique. An exclusive application to lipophilic drug and the extensive nanoparticles washing steps are the drawbacks of this method.

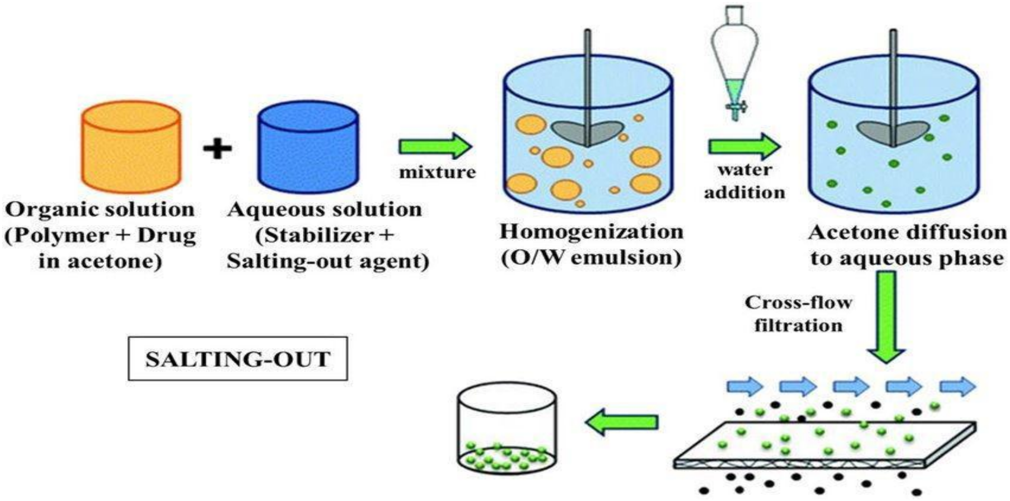


**Fig. 2: Figure showing salting out method.**

### 4. Emulsions Diffusion Method

To prepare nanoparticles, emulsions diffusion method is another method which iscommonly used. The encapsulating polymer is dissolvedin a solvent which is partially miscible with water such as propylene carbonate, benzyl alcohol and the initial thermodynamic equilibrium of both liquids saturated with water should be ensured. Subsequently, The polymer-water saturated solvent phase is emulsified in an aqueous solution containing stabilizer, leading to solvent diffusion to the external phase and according to the oil-to- polymer ratio nanospheres or nanocapsules are formed. Finally, according to boiling point the solvent is removed by evaporation or filtration. This technique has several advantages, such as high reproducibility (batch-to-batch), no requirement of homogenization, high encapsulation efficiencies (generally 70%), simplicity, narrow size distribution and ease of scale-up.

But some drawbacks of this method are: the high volumes of water to be eliminated from the suspension and reduced encapsulation efficiencyduring emulsification becausein the saturated-aqueous external phase leakage of water- soluble drug.[38] Examples of some drug-loaded nano particles which were produced by this technique; cyclosporine (cy-A-); loaded sodium glycolate nanoparticles[39], mesotetra (hydroxyphenyl) porphyrin-loaded PLGA (p-THPP) nano particlesand nano particles of doxorubicin-loaded PLGA.[40-42]

### 5. Solvent Displacement/Precipitation method

Solvent displacement includes from an organic solution, the precipitation of a preformed polymer and in the aqueous medium the diffusion of the organic solvent in the presence or absence of surfactant. In a semi-polar water miscible solvent such as acetone or ethanol, polymers, drug and lipophilic surfactant are dissolved. Then solution is poured or injected using the magnetic stirring, into stabilizer containing aqueous solution. By the rapid solvent diffusion nano particles are formed. Then under reduced pressure solvent is removed from the suspension. The particles size is also affected by rate of addition of the organic phase into the aqueous phase. It was observed that by increasing the rate of mixing, both particles size and drug entrapment decreases.[36] For most of the poorly soluble drugs nano precipitation method is well suited. By adjusting preparation parameters; nanosphere size, and drug release can be controlled effectively. While adjusting concentration of polymer results in good production of smaller sized nanospheres.[43]

## 6. Polymerization Method

In this method, polymerization of monomers is done in an aqueous solution andafter polymerization completed, drug is incorporated either by adsorption onto the nanoparticles or by being dissolved in the polymerization medium. To remove various stabilizers and surfactants, employed for polymerization by ultra centrifugation the nanoparticle suspension is then purified and in an isotonic surfactant-free medium re-suspending the particles. For making polybutyl cyanoacrylate or poly(alkylcyano acrylate) nanoparticles, this technique has been reported.[7] Formation of nanocapsule and their particle size affected by the surfactants and stabilizers concentration used.[44]

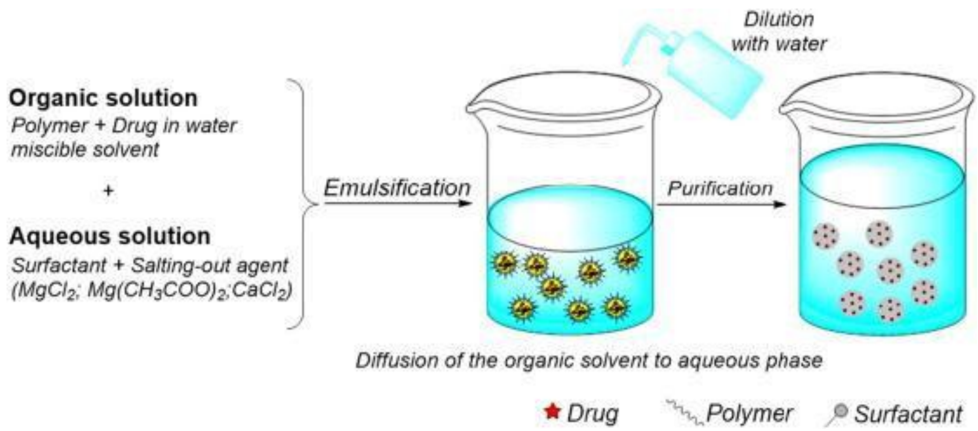


**Fig. 3: Figure Showing Polymerization Method.**

## 7. Coacervation or ionic gelation method

On the preparation of nanoparticles much research has been focused using biodegradable hydrophilic polymers such as chitosan, sodium alginate and gelatin. A method for preparing hydrophilic chitosan nanoparticles by ionic gelation developed by Calvo and co-workers.[39,40] The method contains two aqueousphases, in which one is the polymer chitosan and the other phase is a polyanioni.e. sodium tripolyphosphate In this method, interaction of positively charged amino group of chitosan with negative charged tri polyphosphate occurs which form coacervates with an anometer size range. Electrostatic interaction between two aqueous phases results in the formation of coacervates, while ionic interaction conditions at room temperature results in transition from liquid to gel due to ionic gelation.

### 1.5 Characterization of Nanoparticles

**Zeta potential:** The zeta potential of a nanoparticle is commonly used to characterise the surface charge property of nanoparticles. It reflects the electrical potential of particles and is influenced by the composition of the particle and the medium in which it is dispersed. Nanoparticles with a zeta potential between−10 and +10 mV are considered approximately neutral, while nanoparticles with zeta potentials of greater than+30 mV or less than −30 mV are considered strongly cationic and anionic, respectively. The zeta potential can also be used to determine whether a charged active material is encapsulated within the centre of the nanocapsule or adsorbed onto the surface. The magnitude of the Zeta Potential provides information about particle stability, with higher magnitude potentials exhibiting increased electrostatic repulsion and therefore increased stability.

0-5 mV: Particles tend to agglomerate or aggregate

5-20 mV: Particles are minimally stable

20-40 mV: Particles are moderately stable

40+ mV: Particles are highly stable

It is important to consider that the magnitude of the charge on the nanoparticle surface depends on the solution pH.

The Henry equation is then used to calculate the zeta potential, z:

$$Ue = \frac{2\varepsilon z f(ka)}{3\eta}$$

Where Ue is the electrophoretic mobility, e is the dielectric constant, η is the absolute zero-shear viscosity of the medium, f(ka) is the Henry function, and ka is a measure of the ratio of the particle radius to the Debye length.

**UV-visible absorption spectroscopy:** Absorbance spectroscopy is used to determine the optical properties of a solution. A Light is sent through the sample solution and the amount of absorbed light is measured. When the wavelength is varied and the absorbance is measured at each wavelength. The absorbance can be used to measure the concentration of a solution by using Beer-Lamberts Law. The optical measurement of UV-visible spectrophotometer has different absorbance peak like 410 nm.

**X-ray diffraction (XRD) analysis:** X-ray diffraction is a conventional technique for determination of crystallographic structure and morphology. There is increase or decrease in intensity with the amount of constituent. This technique is used to establish the metallic nature of particles, gives information on translational symmetry size and shape of the unit cell from peak positions and information on electron density inside the unit cell, namely, where the atoms are located from peak intensities.[21] XRD patterns were calculated using X per Rota flex diffraction meter using Cu K radiation and =1.5406 Å. Crystallite size is calculated using Scherrer equation:

CS= K / cos

Where CS is the crystallite size Constant [K] = 0.94 is the full width at half maximum [FWHM] in radius

[β] = FWHM x π /180λ

Cos = Bragg angle. X-ray diffraction analysis with various nanoparticles has been studied by various research workers to find the high crystallinity of the prepared sample.

**Fourier Transform Infrared [FTIR] spectroscopy:** It measures infrared intensity vs. wavelength of light, it is used to determine the nature of associated functional groups and structural features of biological extracts with nanoparticles. The calculated spectra clearly reflect the well-known dependence of nanoparticle optical properties. The green synthesized silver nanoparticle by employing various leaf extract was analysed using Fourier Transform Infrared [FTIR] Spectroscopy showed characteristic peaks.

**Microscopic techniques:** These techniques namely SEM and TEM mainly used for morphological studies of nanoparticles Many researchers used these techniques to show that the synthesized nanoparticles were more or less uniform in size and shape.

**Transmission electron microscopy (TEM):** Transmission electron microscopy is a microscopy technique in which a beam of electrons is transmitted through an ultra-thin specimen, interacting with the specimen as it passes through. An image is formed from the interaction of the electrons transmitted through the specimen; the image is magnified and focused onto an imaging device, such as a fluorescent screen, on a layer of photographic film, or to be detected by a sensor such as a CCD camera. TEM forms a major analysis method in a range of scientific fields, in both physical and biological sciences. TEMs find application in cancer research, virology, materials science as well as pollution, nanotechnology, and semiconductors.

**Scanning electron microscope:** The characterization of Scanning electron microscopic analysis is employed to determine the size, shape & morphologies of formed nanoparticles. SEM gives high resolution images of the surface of a sample as desired. The scanning electron microscope works with same principle as an optical microscope, but it measures the electrons scattered from the sample rather than photon. Because electrons can be accelerated by an electric potential, the wavelength can be made shorter than the one of photons.This makes the SEM capable of magnifying images up to 200,000 times. Measures the particle size and characterization, Conductive or sputter coated sample is involved and the sensitivity down to 1nm.

### 1.6 Applications of NPs

NPs can be used in a variety of applications because to their unique characteristics, as mentioned in Section 4. The following are some of the most important.

#### a. Applications in Drugs and Medications

Nano-sized inorganic particles, whether simple or complex, have unique physical and chemical properties, and are becoming a more important material in the development of novel nanodevices for a variety of physical, biological, biomedical, and pharmaceutical applications Because of their capacity to administer medicines in the optimal dose range, NPs have garnered increasing interest from every area of medicine, frequently resulting in enhanced therapeutic efficiency, reduced adverse effects, and improved patient compliance. The optical characteristics of NPs are used to choose them for creating effective contrast in biological and cell imaging applications, as well as photothermal therapeutic applications. For the most widely utilised types of NPs, such as Au NPs, silica-Au NPs, and Au nanorods, the Mie theory and discrete dipole approximation technique may be used to determine absorption and scattering efficiency as well as optical resonance wavelength. The NPs must have a high magnetization value, a size of less than 100 nm, and a narrow particle size distribution for all of these biological applications (Laurent et al., 2010). Antigen-antibody interactions using antibodies tagged with fluorescent dyes, enzymes, radioactive chemicals, or colloidal Au can be used to identify analytes in tissue slices. Drug delivery research has employed a variety of polymers because they may efficiently carry medicines to the target region, increasing therapeutic effectiveness while reducing adverse effects. A key objective in the design of such devices has been the controlled release of pharmacologically active medicines to the exact action site at the therapeutically optimal degree and dosage regimen. Because of their unique advantages, such as the ability to protect drugs from degradation, target to the site of action, and reduce noxiousness and other side effects, liposomes have been used as a potential drug carrier instead of conventional dosage forms. However, 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, development work on liposome drugs has been limited. Polymeric NPs, on the other hand, offer some significant advantages over these materials, such as liposomes. NPs, for example, aid in the ratability of drugs or problems and have easy-to-use controlled drug release properties. Because of their enhanced light scattering and absorption due to Surface Plasmon.

Resonance (SPR), most semiconductor and metallic NPs have enormous potential for cancer diagnosis and therapy. The strong absorbed light is efficiently converted into localised heat by Au NPs, which can be used for cancer selective laser photothermal therapy. Antimicrobial agents are essential in the textile, medical, water disinfection, and food packaging industries. In comparison to organic chemicals, which are relatively harmful to biological systems, the antibacterial properties of inorganic NPs provide additional power to this crucial feature. These NPs are functionalized with different groups in order to specifically defeat microbial species. Because of their antibacterial efficacies, $TiO_2$, ZnO, $BiVO_4$, Cu, and Ni-based NPs have been used in this study.[45]

**b. Applications in Manufacturing and Materials**

Nanocrystalline materials are fascinating materials for material science because their characteristics differ in size from those of their bulk counterparts. Manufacturing NPs have physicochemical features that provide unique electrical, mechanical, optical, and imaging capabilities that are highly sought after in medicinal, commercial, and environmental applications. NPs are interested in the characterization, design, and engineering of biological and non-biological entities with unique and new functional characteristics that are smaller than 100 nm. Many manufacturers have established the potential benefits of nanotechnology at both a high and low level, and viable products are now being mass-produced in areas such as microelectronics, aircraft, and pharmaceuticals. Metal NPs, such as noble metals such as Au and Ag, exhibit a wide range of visible hues owing to plasmon resonance, which is caused by collective electron oscillations at the NPs' surface. The size and form of the NPs, the interparticle spacing, and the dielectric characteristic of the surrounding medium all influence the resonance wavelength. These noble metal NPs' distinctive plasmon absorbance properties have been used in a number of applications, including chemical sensors and biosensors.

**c. Applications in the Environment**

Engineered NPs are becoming more widely used in industrial and domestic applications, resulting in their discharge into the environment. Understanding the mobility, reactivity, ecotoxicity, and persistence of these NPs in the environment is necessary for assessing their environmental risk The use of engineering materials can raise the concentration of NPs in groundwater and soil, making it one of the most important exposure pathways for assessing environmental hazards .Natural NPs play a crucial role in solid/water partitioning due to their high surface to mass ratio. Pollutants can be absorbed to the surface of NPs, co-precipitated during the production of natural NPs, or confined by aggregation of NPs with contaminants adsorbed to their surface. The size, composition, shape, porosity, aggregation/disaggregation, and aggregate structure of NPs all influence the interaction of pollutants with them. When luminophores are doped inside the silica network, they are shielded from ambient oxygen and are not harmful to the environment. Because of their negative impact on the environment and human health, heavy metals such as mercury, lead, thallium, cadmium, and arsenic have been removed from natural water. For this hazardous soft substance, superparamagnetic iron oxide NPs are an excellent sorbent material. Due to the lack of analytical techniques capable of quantifying trace concentrations of NPs, no measurements of designed NPs in the environment have been provided. Photodegradation by NPs is also a popular method, and a variety of nanomaterials are used for this. The effective photodegradation process was aided by the high surface area of NPs due to their tiny size (10 nm) The same team has reported on the synthesis of a wide range of NPs as well as their optical, florescence, and degradation applications.[46]

**d. Applications in Electronics**

In recent years, there has been a surge in interest in the development of printed electronics, owing to its advantages over traditional silicon methods, as well as the promise for low-cost, large-area electronics for flexible displays and sensors. Printed electronics using various functional inks including NPs such as metallic NPs, organic electronic molecules, CNTs, and ceramic NPs are projected to become a mass manufacturing technique for new types of electronic equipment quickly. One-dimensional semi-conductors and metals have unique structural, optical, and electrical characteristics, making them the essential structural block for a new generation of electronic, sensor, and photonic materials. The electronic industry is an excellent illustration of the synergy between scientific discovery and technical advancement, since novel semiconducting materials led to the transition from vacuum tubes to diodes and transistors, and finally to tiny chips (The ability to include NPs in electric, electrical, or optical systems via "bottom up" or "self-assembly" techniques is one of the most essential aspects of nanotechnology.[47-48]

**e. Applications in Energy Harvesting**

Due to their nonrenewable nature, recent research have cautioned us about the limitations and shortage of fossil fuels in the next years. As a result, scientists are refocusing their research efforts to develop low-cost renewable energy sources from readily available materials. Because of its enormous surface area, optical characteristics, and catalytic nature, they discovered that NPs are the ideal option for this purpose. NPs are frequently utilized to generate energy through photoelectrochemical (PEC) and electrochemical water splitting, particularly in photocatalytic applications. Aside from water splitting and electrochemical $CO_2$ reduction to fuel precursors, advanced energy generation possibilities included solar cells and piezoelectric generators. Nanogenerators have recently been developed that can transform mechanical energy into electricity utilizing piezoelectric technology, which is a novel method to energy generation.[49]

## CONCLUSION

We provide a detailed overview of NPs, their kinds, production, characterizations, physiochemical characteristics, and applications in this study. Nanoparticle technologies have great potentials, being able to convert poorly soluble, poorly absorbed and labile biologically active substance into promising deliverable substances.

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