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Nanoparticles:An Overview Preparation And Characterization

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ABSTRACT
Nanoparticles are extremely small materials that range in size from 1 to 100 nanometers. They can be divided into various categories based on their properties, shapes, and sizes. Nanotechnology is the synthesis and use of materials whose constituents exist at the nanoscale, which is defined as a size of less than 100 nanometers. At the molecular and submolecular level, nanotechnology investigates electrical, optical, and magnetic activity, as well as structural behaviour. It has the potential to transform a variety of medical and biotechnological tools and procedures, making them more portable, affordable, safe, and simple to use. Nanotechnology is the synthesis and use of materials whose constituents exist at the nanoscale, which is defined as a size of less than 100 nanometers. At the molecular and submolecular level, nanotechnology investigates electrical, optical, and magnetic activity, as well as structural behaviour. Chemical or biological methods can be used to make nanoparticles. Metallic nanoparticles come in a variety of forms, including gold, silver, alloys, magnetic nanoparticles, and so on.
Keywords: Nanoparticle, Nanotechnology

I. INTRODUCTION

Nanotechnology is evolving at multiple levels, including materials, systems, and devices. Nanomaterials are currently the most inventive level in commercial applications and scientific information. A particle is a small item that functions as a full unit in terms of attributes and transport in nanotechnology. It can be categorizedaccording to sizes as fine particle and ultrafine particle. Fine particles have a diameter of between 100 and 2500 nanometers, while ultrafine particles have a diameter of between 1 and 100 nanometers. Nanoparticles, like ultrafine particles, are sized between 1 and 100 nanometers. [1]

Classification of nanoparticles: Nanoparticles are classified into several groups based on their shape, size, and chemical characteristics. Some of the most well-known Nanoparticle classes are listed below, based on physical and chemical characteristics:

- **Carbon-based Nanoparticles**: Carbon nanotubes (CNTs) and fullerenes are two primary groups of carbon-based nanoparticles. Nanomaterials made of globular hollow cages, such as allotropic forms of carbon, are found in fullerenes. They've sparked significant commercial interest in nanocomposites for a variety of uses, including fillers, effective gas adsorbents for environmental remediation, and support medium for various inorganic and organic catalysts. [2]
- **Metal Nanoparticles:** Metal precursors are used to make metal nanoparticles. These Nanoparticles have unique optoelectrical qualities due to their well-known localised surface plasmon resonance (LSPR) features. In the visible zone of the electromagnetic sun spectrum, nanoparticles of alkali and noble metals, such as Cu, Ag, and Au, exhibit a large absorption band. Metal synthesis was controlled by facet, size, and shape. Nanoparticles are crucial in today's cutting-edge materials. Metal Nanoparticles are used in a variety of scientific fields due to their excellent optical characteristics. Gold Nanoparticles coating is commonly used for SEM sampling to improve the electronic stream, which aids in the acquisition of high-quality SEM images. [3]
- **Ceramic Nanoparticles:** Ceramic nanoparticles are nonmetallic inorganic solids that are made by heating and cooling. Amorphous, polycrystalline, dense, porous, and hollow shapes are all possible. As a result of its use in applications such as catalysis, photo catalysis, photo degradation of dyes, and imaging applications, these Nanoparticles are attracting a lot of attention from researchers. [4]
- **Semi conductorNanoparticles:**Semiconductor

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materials have qualities that are intermediate between metals and nonmetals, and as a result, they have a wide range of applications in the literature.Due to the huge bandgaps of semiconductor nanoparticles, bandgap tuning resulted in dramatic changes in their characteristics. As a result, they play a crucial role in photocatalysis, photo optics, and electronic devices. [5]

- **Polymeric Nanoparticles:** These are usually organic nanoparticles, and the term polymer nanoparticle (PNP) is used in the literature to describe them. They're generally in the shape of nanospheres or nanocapsules.The former are matrix particles with a solid overall mass, whereas the other molecules are adsorbed at the spherical surface's outer edge. The solid mass is totally enclosed within the particle in the latter situation.[6]

Advantages of Nanoparticles

- To obtain both passive and active medication targeted particle sizes after parenteral injection.
- To achieve high drug therapeutic efficacy and less side effects.
- Site-specific targeting can be achieved.
- The surface characteristics of nanoparticles can be changed for protein, small molecules, peptides, and nucleic acids for targeted medication delivery.
- Drug toxicity can be decreased and drug distribution can be made more efficient by targeting Nano drug carriers.
- The choice of matrix constituents can easily alter controlled release and particle degrading characteristics.
- Liposomes and polymer-based nanoparticles are biodegradable and do not collect in the body, thus they may pose no harm. [7]

Disadvantages of Nanoparticle

- Difficult to produce on a wide scale.
- Particle-particle aggregation can occur due to nanoparticles' tiny particle size and vast surface area, making physical handling of nanoparticles in liquid and dry forms problematic.
- Limited drug loading and burst release are easily achieved due to the small particle size and vast surface area.[8]

Preparation of nanoparticles: The physicochemical characteristics of the polymer and the drug to be loaded influence the method of nanoparticle synthesis chosen. Nanoparticles made from premade polymer can be made in a variety of ways, including:

Emulsion-Solvent Evaporation Method: One of the most common methods for preparing nanoparticles is this procedure. There are two steps to emulsification-solvent evaporation. The polymer solution must first be emulsified into an aqueous phase in the first stage. The polymer solvent is evaporated in the second step, causing the polymer to precipitate as nanospheres. The nano particles are collected by ultracentrifugation and then washed with distilled water to eliminate any remaining stabilisers or free drugs before being lyophilized for storage. The highpressure emulsification and solvent evaporation method is a modification of this process. This procedure begins with the creation of an emulsion, which is then homogenised under high pressure before being stirred to remove the organic solvent. Adjusting the stirring rate, type and amount of dispersion agent1, viscosity of organic and aqueous phases, and temperature can all help control the size. However, this approach can be used with liposoluble medicines, with the scale-up issue posing a constraint. PLA, PLGA, EC, cellulose acetate phthalate, and other polymers are employed in this process.[9,10]

1. **Double Emulsion and Evaporation Method:**Poor entrapment of hydrophilic medicines is a shortcoming of the emulsion and evaporation methods. As a result, the double emulsion approach is used to encapsulate hydrophilic drugs, which includes adding aqueous drug solutions to organic polymer solutions while vigorously swirling to generate w/o emulsions. This w/o emulsion is continuously stirred into the second aqueous phase to generate the w/o/w emulsion. The emulsion is subsequently evaporated to remove the solvent, and nano particles can be separated using high-speed centrifugation. Before lyophilization, the produced nanoparticles must be properly cleaned. The amount of hydrophilic drug to be included, the stabiliser concentration, the polymer concentration, and the volume of aqueous phase are the variables that determine nano particle characterisation in this procedure. [11]

2. **Salting Out Method:**The salting-out action allows a water-miscible solvent to be separated from an aqueous solution. The separation of a

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water miscible solvent from an aqueous solution is based on the salting-out action. The polymer and medicine are first dissolved in a solvent, then emulsified into an aqueous gel using a saltingout agent (electrolytes like magnesium chloride and calcium chloride, or non-electrolytes like sucrose) and a colloidal stabiliser like poly vinyl pyrrolidone or hydroxyl ethyl cellulose. This oil/water emulsion is diluted with enough water or aqueous solution to increase solvent penetration into the aqueous phase, resulting in the creation of nanospheres. Stirring rate, internal/external phase ratio, polymer concentration in the organic phase, type of electrolyte concentration, and type of stabiliser in the aqueous phase are all variables that can be changed during the manufacturing process. This method, which is used to make PLA, Poly(methacrylic) acids, and Ethyl cellulose nanospheres, is highly efficient and may be easily scaled up.Salting out does not require a rise in temperature, it may be advantageous when processing heat-sensitive compounds. The most significant drawbacks are the limited application to lipophilic drugs and the lengthy nanoparticle cleaning procedures. [12]

3. **Emulsions-Diffusion Method:** This is yet another popular approach for making nanoparticles. To ensure the initial thermodynamic equilibrium of both liquids, the encapsulating polymer is dissolved in a partly water-miscible solvent (such as propylene carbonate or benzyl alcohol) and saturated with water.The polymer-water saturated solvent phase is then emulsified in an aqueous solution containing a stabiliser, resulting in solvent diffusion into the exterior phase and the creation of nanospheres or nanocapsules, depending on the oil-to-polymer ratio. Finally, depending on the boiling point of the solvent, it is removed by evaporation or filtration. High encapsulation efficiency (usually 70%), no requirement for homogenization, high batch-to-batch reproducibility, ease of scaleup, simplicity, and a limited size distribution are just a few of the benefits of this approach. High amounts of water must be removed from the suspension, and water-soluble drug leakage into the saturated-aqueous exterior phase during emulsification reduces encapsulation efficiency. The approach was used to create drug-laden sodium glycolate nanoparticles, including mesotetra (hydroxyphenyl) porphyrin-loaded PLGA (p-THPP) nanoparticles, doxorubicin-loaded PLGA nanoparticles, and cyclosporine (cy-A-) loaded sodium glycolate nanoparticles.

4. **Solvent Displacement / Precipitation method:**In the presence or absence of surfactant, solvent displacement entails the precipitation of a preformed polymer from an organic solution and the diffusion of the organic solvent in the aqueous medium. Polymers, drugs, and/or lipophilic surfactants are dissolved in acetone or ethanol, a semipolar water miscible solvent. Under magnetic stirring, the solution is emptied or injected into an aqueous solution containing stabiliser. Rapid solvent diffusion produces nanoparticles almost instantly.

Characterization of Nanoparticles

Nanoparticles are studied using advanced microscopic techniques such as scanning electron microscopy (SEM), transmission electron microscopy (TEM), and atomic force microscopy to determine their size, shape, and surface charge (AFM). The physical stability and in vivo distribution of nanoparticles are influenced by their average particle diameter, size distribution, and charge. The overall morphology of polymeric nanoparticles, which may impact their toxicity, can be determined using electron microscopy techniques. The physical stability and redispersibility of the polymer dispersion, as well as their in vivo performance, are influenced by the surface charge of the nanoparticles.

1. **Particle size**: The most essential parameters in nanoparticle characterisation are particle size distribution and shape. Electron microscopy is used to determine morphology and size. Nanoparticles are most commonly used in medicine delivery and targeting. It has been discovered that particle size has an impact on medication release. The surface area of smaller particles is greater. As a result, the majority of the drug put onto them will come into contact with the particle surface, resulting in rapid drug release. [13]

2. **Zeta potential:**The zeta potential determination of nanocrystals is an important

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characterisation approach for estimating the surface charge that may be used to better understand the physical stability of Nanoparticles. Due to electrostatic repulsion of individual particles, a large positive or negative zeta potential of nanocrystals suggests good physical stability of Nanoparticles. A zeta potential between 230 and 130 mV is commonly thought to have enough repulsive power to provide superior physical colloidal stability. A small zeta potential value, on the other hand, might cause particle aggregation and flocculation due to the van der Waals attractive forces acting on them. Physical instability may arise as a result of several factors. Other parameters, such as material characteristics, the presence of surfactants, and solution chemistry, affect the physical stability of generated nanoparticles in addition to zeta potential values. [14]

3. **Transmission electron microscopy:**Transmission electron microscopy (TEM) is a microscopy technique that takes advantage of the interaction between a thin sample and a uniform current density electron beam (i.e., the energies are usually between 60 and 150 keV). When the electron beam hits the sample, some electrons are transferred and the remainder are elastically or in elastically scattered. The information gathered from the sent electrons is used to create the final image. The most frequent approach for analysing nanoparticle size and form is transmission electron microscopy (TEM), which provides not only direct images of the material but also the most accurate nanoparticle estimation. [15]

4. **Scanning electronic microscope:**Scanning electron microscopy (SEM) allows for direct observation and morphological assessment. Although electron microscopy techniques have significant advantages in terms of morphological and sizing studies, they only provide limited information on the size distribution and genuine population average. For SEM characterization, the nanoparticles solution should first be transformed to a dry powder, which is then mounted on a sample holder and sputter coated with a conducting metal, such as gold. The sample is next scanned with a finely focused electron beam. The secondary electrons emitted from the sample surface are used to determine the sample's surface properties. The nanoparticles must withstand vacuum, and the electron beam may cause damage to the polymer. SEM results are equivalent to dynamic light scattering results in terms of mean size. Furthermore, these methods are time-consuming, expensive, and typically require additional information concerning sizing dispersion. [16-17]

5. **Drug loading:**A successful nanoparticulate system should have a high drug loading capacity, reducing the amount of matrix materials that must be administered. There are two methods for loading drugs:

- Incorporating at the time of nanoparticle production.
- Absorbing the drug after formulation of nanoparticles by incubating the carrier with a concentrated drug solution.

Drug loading and entrapment efficiency are heavily influenced by solid-state drug solubility in matrix materials or polymers, which is influenced by polymer composition, molecular weight, drug polymer interaction, and the presence of an end functional group. [18]

II. CONCLUSION:

Nanoparticles constitute a promising regulated and targeted drug delivery technology. We offered a detailed overview of nanoparticles, their advantages, synthesis, and characterizations in this paper. Nanoparticles have grown important in numerous industries in recent years, including energy, health care, the environment, agriculture, and others, due to their remarkable qualities.Nanoparticle technologies have tremendous potential, as they can transform poorly soluble, poorly absorbed, and labile physiologically active compounds into viable deliverable chemicals. Nanoparticle systems have enormous potential for converting poorly soluble, poorly absorbed, and labile biological active substances into attractive medication delivery methods. Because of their tiny size and relative mobility, nanoparticles have a higher intracellular uptake than microparticles and are available to a wider spectrum of biological targets.

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