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A review: Recent advancement in the formulation and evaluation of the nanoparticles and its application

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Abstract

Due to their unique or superior physical and chemical properties compared to bulk material, nanoparticles have become extremely popular in recent years. The pharmacokinetic and pharmacodynamic properties of many different types of pharmacological compounds have been altered and improved by using particle systems like nanoparticles. They were used in vivo to prevent the drug entity from leaving the systemic circulation, restrict drug access to the targeted areas, and deliver the drug at a steady and controlled rate to the site of action. To maximize therapeutic benefit while reducing adverse effects, a variety of polymers have been utilized in the nanoparticle drug delivery method.

Because of its great selectivity towards the target region, nanotechnology use is significantly important in the field of medicine delivery since it can limit the potentially toxic effects of medication on normal cells. Nanoparticles (NP) play a crucial role and can conjugate with various medications using exact methods to deliver the drug to the target place. The nanoparticle surface is constructed with co-polymers to provide protection from immune cells and ligands to gain affinity inside the course of particular cells. The drug that is attached to nanoparticles can eventually recognize the location, join the target, and enter the cell by receptor-mediated endocytosis. Nanoparticles can then release medications under controlled conditions to treat disorders.

Here, the review gives various aspects of the nanoparticle characterization, formulation, evaluation and application in delivery of drug molecules.

Keyword: Nanoparticle; Formulation of nanoparticle; Evaluation of nanoparticle; Application of nanoparticle

1. Introduction

Particulate dispersions or stable debris having a length between 1 and 1000 nm are referred to as nanoparticles. The medication is dissolved, trapped, enclosed, or joined to a nanoparticle matrix. Nanoparticles, Nano-spheres, or nano-capsules may be acquired depending on method of instruction.Nano-spheres are matrix structures where the drug is freely and equally diffused, where as nano-capsules are systems in which the drug is restricted to a cavity surrounded by a special polymer membrane. Due to their ability to circulate for an extended period of time to target a specific organ, as carriers of DNA in gene therapy, and their capacity to supply proteins, peptides, and genes, biodegradable polymeric nanoparticles particularly those covered with hydrophilic polymers along with polyethylene glycol (PEG) have recently been used as drug delivery devices [1].

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The foremost goals in designing nanoparticles as a transport system are to govern particle length, surface residences and release of pharmacologically active agents that will acquire the drug's site-specific action on the therapeutically most beneficial charge and dose regimen [2].

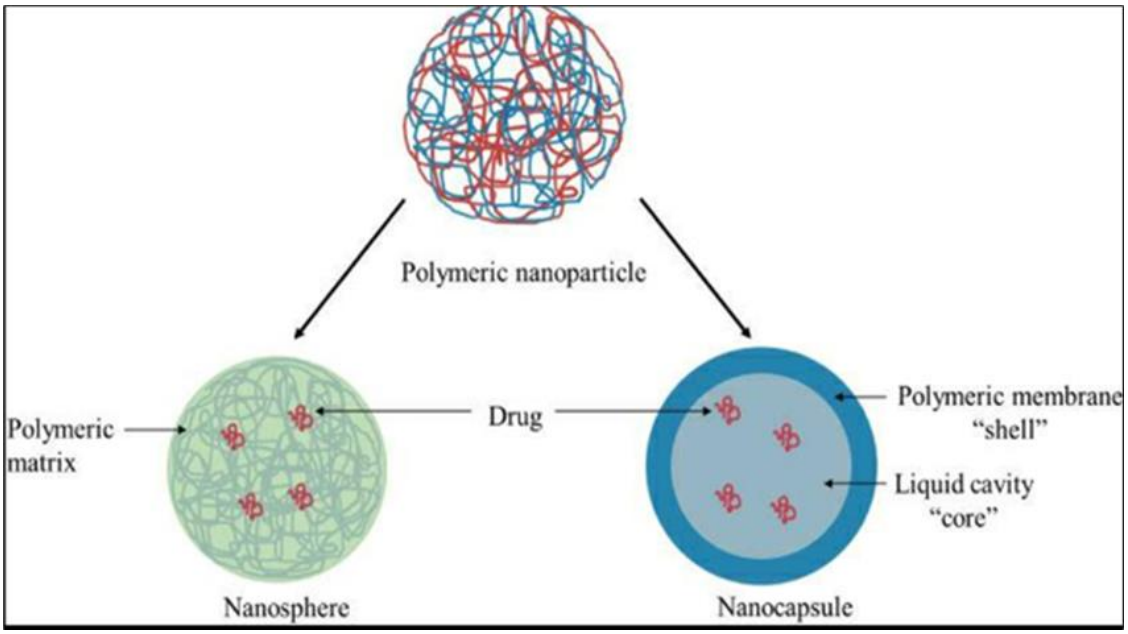

Figure 1 Types of nanoparticle

1.1. Advantages

- It is simple to alter the surface properties and particle size of nanoparticles to enable both passive and active medication targeting after parenteral administration.
- They modify the drug's organ distribution and subsequent clearance to promote therapeutic efficacy and decrease side effects by controlling and maintaining the release of the drug throughout transportation and at the site of localization.
- The properties of controlled release and particle disintegration can be readily modified by the selection of matrix constituents.
- Drugs may be integrated into the systems without causing any chemical reactions, which is a key aspect of maintaining the drug's activity. Drug loading is also rather high.
- Targeting ligands can be attached to the surface of particles to achieve site-specific targeting, or magnetic guiding can be used.
- The system can be used for various routes of administration including oral, nasal, parenteral, intra-ocular etc [1].
- Higher Stability
- Higher Carrier Capacity
- Feasibility of variable routes of administration
- These are biodegradable, non-toxic & capable Stored for a longer period.
- Also used Controlled delivery.
- Reduces dosing frequency [3].

1.2. Disadvantages

- Posses limited drug loading capacity.
- On repeated administration, toxic metabolites may be formed during the polymeric carrier's biotransformation.
- Relatively slowly biodegradable which might cause systemic toxicity [3].

2. Properties of Nanoparticles

The nanoparticles are of different size, shape and structure. It is spherical, cylindrical, tubular, conical, hollow middle, spiral, flat, and so forth or extraordinary and differs from 1 nm to a 100 nm in length. The surface may be a uniform or

weird with surface variation [4]. Few nanoparticles are crystalline or amorphous with single or multi crystal solids each agglomerated. Material properties rely upon form and composition and may normally be engineered or modified with the aid of way of converting the relative impact of interfacial or interphase properties and the macroscopic bulk properties through the feature size or dimension of components and domain. This approach had already emerged centuries ago with steel alloys and has been so effective that many engineering materials these days are composites with micro to nanoscale vicinity sizes.

Depending on the physical or chemical character of every area, there is a complex interrelation between the structure and the composition of the material, which may additionally relate to the majority and surface properties of every issue and newly growing characteristics localized on the interface. Selective chemical reactivity is a quite common with Nano composites, which offers the functionality of disintegration of the material into one or the alternative issue. Complex methods govern this behavior, which simply relates to nanoparticle release into the surroundings [5].

3. Formulation of nanoparticle

3.1. Precipitation system

This system is finding from 1980 for manufacturing of nanoparticles. This is easy method wherein API is solubilize in natural solvent and excipients like polymer surfactant and stabilizer are dissolved in a miscible inorganic solvent than with spontaneous agitation addition of organic solvent into inorganic solvent is completed and it supply precipitation of debris. This generation is simple and want regulation cost so examine with different techniques this process is simple and need much less time for success. For performing this approach we require the solubility of API as a minimum in a single organic solvent and that natural solvent have properties to miscible with inorganic solvent so that is limits of this technique [6].

3.2. Milling system

This technology is advanced in 1990. In this technique API and surfactant are charged with milling pearls and fill in chamber of milling after which excessive rotation is implemented by using a motor and nanoparticles are shape in suspension shape. This process want long time for production due to the fact drug hardness and quantities like element may also have an effect on this method. This technique desires high strength and every so often erosion of pearls leads product degradation and delivers risk of bacterial and micro logical infection. The media milling chamber is produce via the usage of zirconium oxide, glass or polystyrene resin. The milling method is used for aqua and organic medium. It is able to use in both scenario to supply diluted as well as concentrated suspension method. This technique have disadvantage is it administer long time and milling might also provide instability to suspension [7]

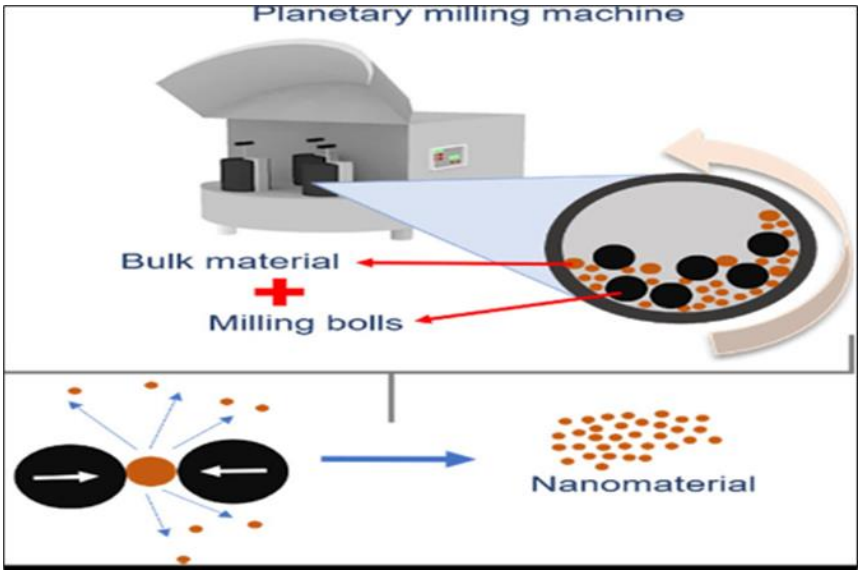

Figure 2 Milling machine

4. Production of Nanoparticle in Nonaqueous Method

4.1. Method of Pelletization

In general, nanosuspensions are stable; however, in particular situations, such as oral administration, and stability issue we need solid formulation so, this technique is usable for this problem solution. By applying techniques like lyophilization, spray drying, extrusion, and spheronization, or by layering on sugar pellets, nanosuspension is transformed into solid form. Using an extrusion technique, the final product is produced using this procedure, which involves mixing a suspension with the matrix excipients. The substance is forming free-flowing, small, spherical pellets in the shape of the material [8].

4.2. Production Process for Hot Melted

This approach involves applying homogenization at a high temperature to melted material. Temperature is a decision based on the melting point of the material matrix being employed. Because the container is covered with temperature control jackets, the Micro Lab 40 homonizer is typically utilized for this approach. This process moves on to solidification, which is accomplished at room temperature by cooling once the desired particle size has been attained [9].

4.3. Direct Compression Method

The nanoparticle powder is obtained from nano suspension by using spray drying or any other method and which can use orally by filling it into capsule. In case of acid sensitive drug nanoparticle are fill into hard gelatin capsule. The other way of applying nanoparticle as orally is convert it into tablet formulation. For that drug nano suspension is mixed with matrix forming material like micro size polymer powder or lipid and lactose powder and then spray drying is apply. By this process the liquid phase is go into API-matrix compound and convert into free flowing powder than direct compression is apply and which give long release tablet formulation [8].

5. Evaluation of nanoparticle

5.1. Analysis of Particle Sizes

The scanning electron microscope was used to measure the nanoparticles particle size. Depending on the polymer load, particle size ranges from 350 nm to 600 nm [10].

5.2. Scanning Electron Microscopy (SEM)

Using scanning electron microscopy, the surface morphology and particle form of nanoparticles were studied. Lyophilized samples that were totally free of moisture were placed on aluminum stubs using adhesive tapes, coated with gold using a sputter coater, and then examined for morphology at a 20 kV acceleration voltage [2].

5.3. Differential Scanning Calorimetry (DSC)

The natural drug's physical state with the help of a DSC study (DSC-60, Shimadzu, Japan), nanoparticles were identified. About 2 mg of native drug, polymer, and nanoparticles were inserted separately into various sealed standard aluminum pans and heated at a rate of 10°C/min under nitrogen environment before being heated to various temperatures between 25 and 300 °C. The standard was an aluminum pan that was empty [2].

5.4. X-ray Diffraction Analysis

An XRD-6000 diffractometer was used to carry out the X-ray diffraction analysis. Diffraction of X-rays formulation and the pure drug's crystallinity were determined through analysis. In a sample holder made of aluminum, the powder was placed. 30 mA and 40 kV were used to create Cu radiation. As previously mentioned, samples were scanned between 10° and 90° at a speed of 10° min-1 [11].

5.5. Analysis of Fourier Transform Infrared (FTIR) Spectroscopy

The chemical stability and potential chemical (Perkin Elmer, FTIR Spectrometer, SPECTRUM RX I, USA) FTIR analysis can be used to assess how the medication and polymer interact. To create the pellets, samples were each separately combined with 200–400 mg of potassium bromide and crushed for two minutes at 200 kg/cm2 pressure. Placing the

pellets of the natural drug, polymer, and drug-loaded nanoparticles on the light path allowed for analysis. All averaging 32 interfero grams with a resolution of 2 cm1 over a range of 4000-400 cm1 was used to scan all samples [2].

5.6. Study of Accelerated Stability

The samples were kept in borosilicate glass vials with the nanoparticles inside of them climatically controlled environmental simulation chambers. Storage conditions and number of samples used in safety studies comply with International Conference on Harmonization (ICH) guidelines. By dispersing 1 mg of drug-loaded Eudragit®RS100 nanoparticles in 10 ml of distilled water, physical and chemical characterization of the drug-loaded Eudragit®RS100 nanoparticles was conducted over a period of six months at regular intervals to look for any deterioration. On occasion, the studies were done in three copies. With the use of a Zeta sizer, which is based on quasi-elastic light scattering, particle size and zeta potential were determined at a certain wavelength and 25°C.RP-HPLC at 282 nm was used to test the formulation's chemical stability (drug content) [12].

6. Application

6.1. Therapeutic applications of Polymeric nanoparticles

- They create novel medication delivery systems for the treatment of neurodegenerative and brain-related diseases using polymeric nanoparticles.
- Drugs are protected by polymeric NPs by being encapsulated, trapped inside the core, or adsorbing on to the particle surface.
- Polymeric NPs use the endocytosis and transcytosis pathways to transport molecules with across through the BBB.
- This polymeric covering is expected to lessen immunogenicity and restrict the reticuloendothelial system's ability to phagocytose nanoparticles, leading to increased blood levels of the drug in organs like the brain, intestines, and kidneys.
- These have been used in gene therapy to have an antiproliferative effect on breast cancer cells [13].

6.2. Nanoparticles for gene delivery

Polynucleotide vaccines function by introducing relevant antigen-coding genes into host cells where they are expressing, generating the antigenic protein close to expert antigen-presenting cells to trigger an immune response. Because intracellular protein synthesis, as opposed to extracellular protein deposition, stimulates both the humoral and cell-mediated immune systems, such vaccines result in both. DNA, the primary component of polynucleotide vaccines, is significantly easier to manufacture and has better storage and handling characteristics than the majority of protein-based vaccines components. Due to their quick transition from the degradative endo-lysosomal compartment to the cytoplasmic compartment, nanoparticles loaded with plasmid DNA may also function as an effective sustained release gene delivery device. Utilizing PLGA nanoparticles harboring therapeutic genes, such as those involved in bone repair, this gene delivery technique as morphogenic proteins for bone [14].

6.3. Nanoparticles for drug delivery into the brain

The blood-brain barrier (BBB) is the primary barrier preventing the creation of novel medications for the central nervous system network of nerves. Endothelial cells with tight connections, enzymatic activity, and active efflux transport mechanisms, which are relatively impermeable, characterize the BBB. It successfully blocks the entry of water-soluble molecules from blood circulation into the CNS and, through the action of enzymes or efflux pumps, can also lower the concentration of lipid-soluble molecules in the brain. As a result, the BBB only allows for the selective transit of chemicals that are necessary for brain activity [15].

6.4. Antibody targeting of nanoparticles

Numerous studies have shown the use of antibody-mediated nanoparticles to create targeted drug delivery systems, particularly in the context of cancer treatment. Antibodies that target drug substances have the potential to enhance the therapeutic efficacy of the drug substance as well as the concentration and distribution of the medication at the intended site of action [16].

7. Conclusion

The instances that were above demonstrate the immense potential of nanoparticulate systems, including their ability to create promising deliverable medications from poorly soluble, poorly absorbed, and labile physiologically active substances. The hydrophilic shell of this system's center, which hinders recognition by the reticular-endothelial system, results in long circulation duration and the ability to contain a range of medicines, enzymes, and genes. More research into the various biological interaction processes and particle engineering are still needed to enhance this medication delivery technology. A concept of nanoparticle technology needs to be developed further in order to become a viable, workable application as the next generation of medication delivery systems.

Nanoparticle research has grown to be one of the most crucial fields of current study because of the unique properties that nanoparticles give materials. When the identical material generated at the nanoscale has various advances over a material with larger grain size because of its noticeably superior and distinctive properties. After their initial appearance in science, high costs have increased in frequency, the price has decreased to acceptable levels, and new nanomaterials are being created every day. Recently, particularly in some industries, the use and potential of nanoparticles have increased. Recent years have seen a significant amount of research and development in the fields of drug delivery, cancer treatment, and the production of high-strength materials. It seems that serious efforts will be made to further nanoparticle research.

Many believe that the use of nanotechnology in medication delivery will lead to the development of innovative therapies that could completely alter the pharmaceutical and biotechnology sectors. There are several areas of interest where there will be efficient and safer targeted treatments for a variety of clinical applications that are being researched using various nanotechnology platforms, either in the development or in the clinical phases. It will soon be evolving out for the benefit of all humanity.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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