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Nano-Particles Drug Delivery System

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ABSTRACT:

Particle delivery systems have garnered significant research interest in recent decades as carriers for both small and large molecules in drug delivery. The utilization of particulate systems, such as nanoparticles, has been employed to modify and enhance the pharmacokinetic and pharmacodynamic properties of numerous medicinal compounds. (1) Nanoparticles exhibit immense potential as effective drug delivery systems.

This review discusses recent advancements in nanotechnology for drug delivery. To overcome the challenges associated with gene and drug delivery, nanotechnology has gained considerable interest in recent years. Nano systems with diverse compositions and biological properties have been extensively investigated for drug and gene delivery applications. (45)

This paper provides a comprehensive overview of the fabrication, characteristics, and applications of nanoparticles (NPs), which exist in various forms. NPs are minuscule particles ranging in size from 1 to 100 nanometers. They can be classified into several categories based on their properties, sizes, or shapes. Some common types include fullerenes, metal nanoparticles, ceramic nanoparticles, and polymeric nanoparticles.

Due to their large surface area and nanoscale dimensions, NPs possess unique physical and chemical properties. According to reports, their size significantly influences their optical properties, resulting in distinct colors due to absorption in the visible spectrum. Their unique size, shape, and structure also impact their strength, reactivity, and other characteristics. These properties make them suitable candidates for a wide range of applications, including imaging, energy-based research, medical applications, environmental applications, and catalysis.

Heavy metal nanoparticles, such as those of lead, mercury, and tin, are known for their exceptional strength and rigidity, making them difficult to degrade. This characteristic can lead to various environmental toxicities.

Introduction

Drug delivery vehicles, or nanoparticles, are typically composed of various biodegradable materials, including metals, lipids, or natural or synthetic polymers. These particles are typically less than 100 nanometers in at least one dimension. Since nanoparticles are more readily absorbed by cells than larger molecules, they can be effectively employed as delivery and transport vehicles. (2)

Nanotechnology offers numerous advantages in pharmaceutical applications, including:

- * Increased surface area
- * Enhanced solubility
- * Increased rate of dissolution
- * Increased oral bioavailability
- * Reduced dosage requirements and decreased frequency of administration
- * Protection of drugs from degradation
- * More rapid onset of therapeutic action

* Achievement of drug targeting

* Passive targeting of drugs to macrophages present in the liver and spleen (39)

For applications in medicine and physiology, these materials and devices can be designed to interact with a high degree of functional specificity, enabling a level of interaction between technology and biological systems previously unattainable.

It's crucial to recognize that nanotechnology is not a single emerging scientific discipline but rather a convergence of traditional sciences such as chemistry, physics, materials science, and biology, bringing together the collective expertise required to develop these novel technologies.

Since the previous century, nanotechnology has been a recognized area of research. Numerous revolutionary advancements have been made in the field of nanotechnology since Nobel laureate Richard P. Feynman introduced the concept in his renowned 1959 speech, "There's Plenty of Room at the Bottom." Nanotechnology has enabled the creation of materials of various kinds at the nanoscale level.

Particulate materials with at least one dimension smaller than 100 nanometers fall under the broad category of nanoparticles (NPs). Although nanotechnology and nanomaterials have advanced significantly over the past two decades, potential toxicological effects on humans, animals, and the environment have not received sufficient attention.

Furthermore, despite the primary objective of nanomedicine being to enhance human health, numerous researchers have reported that NPs can be intentionally exploited for various purposes, potentially increasing their toxicity. (4,5)

Additionally, synthesis methods for NPs or nanomaterials (such as carbon nanotubes [CNTs]) often involve.

1.Targeting strategies

"Mihail (Mike) Roco of the U.S. National Nanotechnology Initiative has outlined four stages of nanotechnology development. Currently, we are in the first stage, characterized by passive nanostructures – materials designed for a single function.

The second stage, now underway, introduces active nanostructures with multiple capabilities, such as actuators, drug delivery systems, and sensors. The third stage, anticipated to have begun around 2010, involves Nano systems with thousands of interconnected components.

Following this, the fourth stage will see the emergence of integrated Nano systems, operating similarly to a mammalian cell with intricate hierarchical structures.

While some researchers may still view nanotechnology solely as the measurement and visualization of structures within the 1-10 nanometre range, a growing consensus, championed by Dr. Roco, emphasizes the critical role of controlling and manipulating matter at the nanoscale."(30)

1st: passive nanostructures

a.dispersed and contact nanostructures Ex:aerosols,colloids

b.products incorporating nanostructures Ex:coatings ,nanoparticle reinforced composites; nanostructured metals, polymers ,ceramics

2nd: Active nanostructures

a.bio-active ,health effects Ex:targeted drugs, biodevices

b.physico-chemical active Ex:3D transistors, amplifiers,actuators,adaptive structure

3rd:systems of Nano systems

Ex: guided assembling ;3D Networking and new hierarchical, robotics architectures,evaluation

4th: Molecular Nano systems

Ex: molecular devices by design, atomic design , emerging functions

-2015-2020

Fig. 1Representing the four generations of nanoparticle

2. PHARMACEUTICAL NANOTECHNOLOGY BASED SYSTEMS

Pharmaceutical nanotechnology encompasses two primary categories: nanomaterials and nanodevices. These components play a crucial role not only in pharmaceutical applications but also in various other fields.

2.1 Nanomaterials

These materials are often derived from biocompatible sources and find applications in fields like orthopaedics and dentistry, where they serve as implants or scaffolds for tissue engineering. Their surfaces can be modified or coated to enhance their compatibility with living cells. Nanomaterials can be further classified into two main types:

2.2 Nanocrystalline Materials

Nanocrystalline materials are readily manufactured and can effectively replace less performing bulk materials. These materials find direct application in drug encapsulation, bone replacement, prostheses, and implants.

2.3 Nanostructured Materials

Nanostructured materials are processed forms of nanomaterials with unique shapes and functionalities. Examples include quantum dots, dendrimers, fullerenes, and carbon nanotubes.

2.4 Nanodevices

Nanodevices are miniature devices operating at the nanoscale. They encompass Nano and microelectromechanical systems (NEMS/MEMS), microfluidics, and micro assays. They also include biosensors and detectors, which play a crucial role in diagnosis. (1)

3. Classification of Nano particles

Nanoparticles (NPs) can be broadly classified into various categories based on their morphology, size, and chemical properties. Some of the well-known classes of NPs based on their physical and chemical characteristics are as follows:

1. Carbon-based NPs:

- * Fullerenes: These are allotropic forms of carbon, consisting of globular hollow cages.
- * Carbon Nanotubes (CNTs): These are cylindrical structures formed by rolled sheets of carbon atoms. They can be classified as single-walled (SWNTs), double-walled (DWNTs), or multi-walled carbon nanotubes (MWNTs) depending on the number of layers.

Carbon-based NPs exhibit exceptional properties such as high strength, electrical conductivity, and versatility, attracting significant commercial interest. Common production methods include electric arc, laser vaporization of graphite, and chemical vapor deposition (CVD) (31).

2. Metal NPs:

Metal NPs consist solely of their metallic precursor. They exhibit distinct optoelectronic characteristics due to their localized surface plasmon resonance (LSPR) properties.

- * Nanoparticles of alkali and noble metals, such as Cu, Ag, and Au, exhibit a broad absorption band within the visible region of the electromagnetic spectrum.

- * In contemporary materials science, the controlled synthesis of metal NPs with specific facets, sizes, and shapes is of paramount importance (32).

3.3 Ceramics NPs:

Inorganic non-metallic solids, or ceramic nanoparticles, are created by heating and then cooling a material. They exist in forms that are porous, hollow, dense, polycrystalline, and amorphous (33)

3.4 Semiconductor NPs:

Because semiconductor materials have characteristics in between those of metals and non-metals, they have been used in a variety of ways in the literature (34). Due to their large bandgaps, semiconductor nanoparticles (NPs) exhibit notable characteristics changes upon bandgap adjustment. As a result, they are crucial components for photocatalysis, photonics, and electrical devices. (35)

3.5 Polymeric NPs:

These are typically organic-based NPs, and they are collectively referred to in the literature as polymer nanoparticles (PNPs). Most of them have the shape of nanospheres or noncapsular. (36) .. The other molecules are adsorbed at the external side edge of the spherical surface, but the former are matrix particles with an overall mass that is often solid. In the latter instance, the solid mass is entirely contained within the particle (37)

3.6 Lipid-based NPs:

These NPs are useful in a variety of biological applications because they include lipid moieties. A lipid nanoparticle (NP) typically has a spherical diameter that ranges from 10 to 1000 nm. Lipid NPs, like polymeric NPs, are composed of a solid lipid core surrounded by a matrix of soluble lipophilic molecules. The exterior core of these NPs was stabilized by surfactants or emulsifiers (38)

4. Synthesis of nanoparticles

Various methods can be employed for the synthesis of NPs, but these methods are broadly divided into two main classes

4.1 Bottom-up approach

This strategy is applied in reverse as NPs are created from relatively simpler compounds, so this approach is also called building up approach. Techniques for reduction and sedimentation are examples of this. It consists of spinning, biological synthesis, green synthesis, and sol gel (40). These NPs have superior colloidal characteristics. In the top-down method, bismuth was first transformed into a molten drop, which was then emulsified inside the cooked diethylene glycol to make the NPs. In the bottom-up approach, bismuth acetate was heated within ethylene glycol. The two methods yielded NPs ranging in size from 100 nm to 500 nm. (41)

4.2 Top-down syntheses

Destructive approach is used in this strategy. Larger molecules were first broken down into smaller components, which were subsequently transformed into acceptable nanoparticles. As an illustration CVD, physical vapour deposition (PVD), grinding/milling, and other breakdown techniques are examples of this approach. According to one study, spherical magnetite nanoparticles (NPs) with a particle size ranging from about 20 to about 50 nm were synthesised from natural iron oxide (Fe_2O_3) ore using a top-down destructive technique in the presence of organic oleic acid (42)

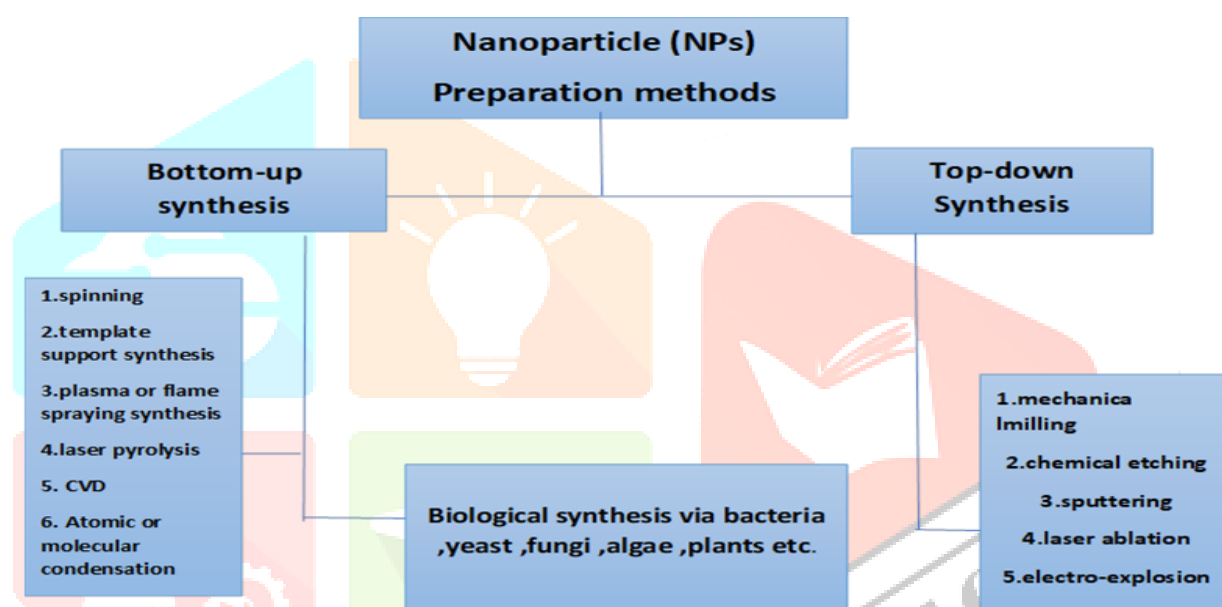
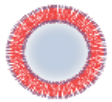
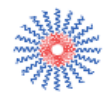
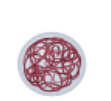
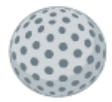
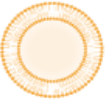


Fig.2 Typical synthetic methods for NPs for the (a) top-down and (b) bottom-up approaches (43)

5. TYPES OF PHARMACEUTICAL NANO SYSTEMS:

Classes of Nanoparticles

Polymeric	Inorganic	Lipid-based
 Polymersome  Dendrimer  Polymer micelle  Nanosphere	 Silica nanoparticle  Quantum dot  Iron oxide nanoparticle  Gold nanoparticle	 Liposome  Lipid nanoparticle  Emulsion
Advantages - Precise control of particle characteristics - Payload flexibility - Easy surface modification Disadvantages - Possibility of aggregation and toxicity	Advantages - Unique electrical, magnetic, optical properties - Variability in size, structure, geometry - Suited for theranostic applications Disadvantages - Toxicity and solubility limitations	Advantages - Formulation simplicity - High bioavailability - Payload flexibility Disadvantages - Low encapsulation efficiency

5.1 Carbon nanotubes

Carbon nanotubes are cylindrical structures composed of hexagonal networks of carbon atoms. These structures exhibit a significant length-to-diameter ratio with diameters typically ranging from 1 to 100 nanometres.

Two primary types of carbon nanotubes exist:

- * Single-walled nanotubes (SWNTs): Composed of a single layer of carbon atoms.
- * Multi-walled nanotubes (MWNTs): Composed of multiple concentric layers of carbon atoms.

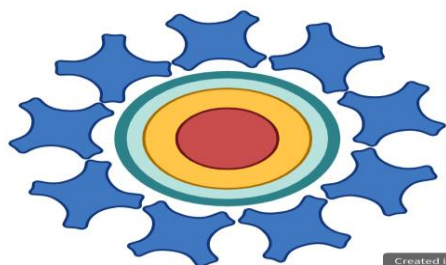
These nanoscale macromolecules possess unique size, shape, and remarkable physical properties(3).

Carbon nanotubes are characterized by their distinctive tubular structure. They can consist of one, several hundred, or even thousands of concentric carbon shells separated by approximately 0.34 nanometres. The arrangement of carbon atoms within these shells resembles the honeycomb configuration found in graphite sheets.

The unique one-dimensional (1D) structure of nanotubes, coupled with the graphite-like arrangement of carbon atoms within the shells, is responsible for their exceptional mechanical and electrical properties.

Due to their high tensile strength and Young's modulus, carbon nanotubes are highly sought after for reinforcing composite materials to enhance their mechanical performance(6).

5.2 Quantum Dots



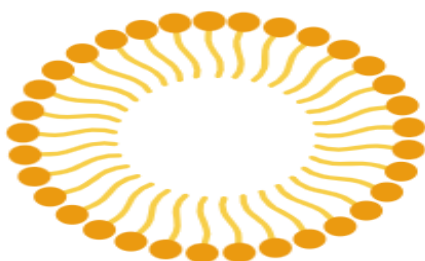
Quantum dots are semiconductor nanocrystals, typically ranging in size from 2 to 10 nanometers. They consist of a semiconductor core often coated with a shell to enhance their optical properties.

The unique properties of quantum dots stem from their nanoscale dimensions, typically ranging from 10 to 100 Angstroms in radius. These properties have significant implications in various fields, including:

- * Imaging: Enabling advanced imaging techniques.
- * Biomolecule Detection: Facilitating in vitro and in vivo detection and analysis of biomolecules.
- * Immunoassays: Enhancing the sensitivity and specificity of immunoassays.
- * DNA Hybridization: Improving the detection of DNA hybridization events.
- * Gene Therapy: Serving as non-viral vectors for gene delivery.
- * Cancer Treatment: Showing promise as therapeutic tools for cancer treatment.

Quantum dots are commonly composed of atoms from Group II-VI or III-V elements in the periodic table. Some of the most widely used quantum dots include indium arsenide (InAs), cadmium telluride (CdTe), and cadmium selenide (CdSe)(5).

5.3 Colloidal Nano-liposomes:



Liposomes are small, spherical, artificial vesicles composed of a bilayer of amphiphilic phospholipids and often incorporating cholesterol. They encapsulate an aqueous core. Their size, ability to encapsulate both hydrophilic and hydrophobic molecules, and excellent biocompatibility make them widely used in various applications.

Based on their size and number of phospholipid bilayers, liposomes can be categorized as:

- * Multilamellar Vesicles (MLVs): These consist of multiple concentric lipid bilayers separated by aqueous spaces. MLVs are heterogeneous in

size, typically ranging from a few hundred to several thousand nanometres in diameter(8).

- * Small Unilamellar Vesicles (SUVs): These are single-layered vesicles with diameters typically ranging from 25 to 50 nanometres.

- * Large Unilamellar Vesicles (LUVs): These are single-layered vesicles with diameters larger than 100 nanometers(9).

Both SUVs and LUVs consist of a single lipid bilayer that encloses an aqueous core.

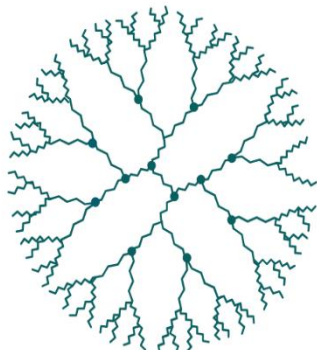
Depending on the physicochemical properties of the drug, it can either be intercalated within the lipid bilayer of the liposome or entrapped within the aqueous core.

Liposomes can be engineered with a wide range of variations in their size, flexibility, content, structure, and surface modifications to facilitate both active and passive delivery of bioactive materials.

Applications of liposomes include:

- * Leishmaniasis treatment
- * Pulmonary drug delivery
- * Antigen delivery
- * Cancer treatment
- * Ocular drug delivery

5.4 Dendrimers



Dendrimers are synthetic, three-dimensional, highly branched macromolecules with well-defined, monodisperse structures and nanoscale dimensions. They are characterized by a central core from which multiple branches emanate, resulting in a globular architecture.

A typical dendrimer comprises three distinct topological components:

- * Core: The central core of the dendrimer.
- * Internal Layers: Consisting of repeating units that form the branching structure.
- * Peripheral Functional Groups: Located at the outermost surface of the dendrimer.

These structures resemble trees and are often described as "hyperbranched." They are essentially compartmentalized polymers with a well-defined

architecture.

- * Core: The central portion of the dendrimer.
- * Branches: Radiate outwards from the core, creating an interior hollow space and a sphere of terminal functional groups.
- * Surface: The outermost layer of the dendrimer, where the functional groups are located. The branches of dendrimers are highly adaptable and can be modified to suit specific applications. Through careful design, dendrimers can be engineered to exhibit enhanced biocompatibility, low cytotoxicity, and high bio permeability.

Dendrimers can be utilized to deliver bioactive molecules, such as drugs, vaccines, genes, and other therapeutic agents, to specific target sites. These molecules can be either encapsulated within the interior cavity of the dendrimer or attached to the peripheral functional groups(12)

SOME OF THE SELECTED DRUGS AS NANO DRUG DELIVERY SYSTEMS NANOPARTICLE (44)

6. Effect of Characteristics of Nanoparticles on Drug Delivery

6.1 Particle size

Particle size and its distribution are critical characteristics of nanoparticle systems. They significantly influence various aspects, including (13).

- * In vivo distribution: How nanoparticles travel and accumulate within the body.
- * Biological fate: Their interactions with biological systems (e.g., uptake, metabolism, elimination).
- * Toxicity: Potential adverse effects on the body.
- * Targeting ability: Their ability to specifically deliver drugs to target sites.
- * Drug loading: The amount of drug that can be encapsulated within the nanoparticles.
- * Drug release: The rate and extent of drug release from the nanoparticles.
- * Stability: The stability of the nanoparticle formulation over time.

Due to their small size and enhanced mobility, nanoparticles can access a wider range of biological targets compared to microparticles. They generally exhibit higher intracellular uptake. Desai et al. demonstrated in a

Sr.no	Name of the drug	purpose
1)	Clonazepam	To determine the drug loading capacity and release profile
2)	Morphine	To study pain-relieving properties and delivery to the brain (by nasal route)
3)	Dexamethasone	To increase drug release compared to the pure drug.
4)	Amoxicillin	To evaluate the effectiveness against Helicobacter pylori infection
5)	Aspirin	to achieve slow and sustained drug release
6)	salbutamol suyate	The achieved size and shape of nanoparticles are suitable lung deposition (inhalation)
7)	Amphotericin B	To improve oral bioavailability and reduced kidney toxicity compared to intravenous
8)	Rifampicin	To formulate a dry powder for inhalation delivery with long shelf life, dispersibility, and extended release for localized lung and systemic action
9)	Ketoprofen	To study the interaction between the drug and various acrylic polymers
10)	Cyclosporin A	to create a stable suspension of submicron particles .
11)	Lamivudine	Increased bioavailability observed in AIDS patients .
12)	Indomethacin	To enhance sustained release and delay clearances without affecting its metabolism
13)	Curcumin	To improve transport to the brain and delivery across the blood brain barrier
14)	Docetaxel	For effective delivery of drug to solid tumour
15)	Estradiol	To increase oral bioavailability of Estradiol. (oral)

Caco-2 cell line study that 100 nm nanoparticles exhibited 2.5-fold higher uptake than 1 µm microparticles and 6-fold higher uptake than 10 µm microparticles (14).

Particle size also significantly impacts drug release kinetics.

- * Smaller particles: Typically exhibit a larger surface area-to-volume ratio. This leads to a higher proportion of the drug being located at or near the particle surface, resulting in rapid drug release.

* Larger particles: Can encapsulate a greater amount of drug within their larger core, potentially enabling slower and more sustained drug release(15).

6.2 Surface properties of nanoparticles

When nanoparticles are administered intravenously, they are easily recognized by the body immune systems, and are then cleared by phagocytes from the circulation (16)

A common approach to describe a nanoparticle's surface charge attribute is to use its zeta potential. It is impacted by the makeup of the particle as well as the medium in which it is distributed, and it reflects the electrical potential of particles. It has been shown that nanoparticles getting zeta potentials above (+/-) 30 mV are stable in suspension because their surface charge keeps the particles from aggregating. If a charged active material is adsorbed onto the surface or contained within the centre of the Nano capsule, it can also be determined using the zeta potential. (17)

6.3 Drug loading

A crucial aspect of successful nanoparticle drug delivery systems is achieving high drug loading capacity. This minimizes the amount of carrier material required for administration.

Two primary methods for drug loading into nanoparticles include:

- * Incorporation Method: The drug is incorporated into the nanoparticles during their synthesis or fabrication.
- * Absorption/Adsorption Method: The drug is loaded onto the pre-formed nanoparticles by incubating them with a concentrated drug solution.

Drug loading and entrapment efficiency are significantly influenced by the solubility of the drug within the carrier material or polymer matrix. This solubility is dependent on several factors, including:

- * Polymer Composition: The type and properties of the polymer used.
- * Molecular Weight: The molecular weight of both the drug and the polymer.
- * Drug-Polymer Interactions: The nature and strength of interactions between the drug and the polymer matrix (e.g., hydrogen bonding, electrostatic interactions).
- * Presence of End Groups: The presence of functional groups on the polymer, such as esters or carboxyl groups, which can influence drug-polymer interactions(18) (19)

7. APPLICATIONS OF PHARMACEUTICAL NANOTECHNOLOGY

Miniaturization has revolutionized pharmaceutical technology. While increasing complexity, it has also brought about numerous benefits in drug delivery and diagnostics. The various pharmaceutical and biochemical areas where Nano systems are utilized include:

7.1 Nanomaterials for Tissue Engineering

Nanomaterials offer significant potential in tissue engineering applications, including:

- * Tissue regeneration
- * Implant coatings
- * Bone reconstruction
- * Development of structural implant materials
- * Tissue repair
- * Bioresorbable materials

Furthermore, nanotechnology finds applications in:

- * Surgical instruments
- * Operating instruments
- * Implantable devices (such as retinal implants, sensory aids)
- * Smart instruments

7.2 Drug Carrier Systems

Nanomaterial-enabled drug delivery systems exhibit improved physical, chemical, and biological properties, making them valuable tools for administering bioactive agents. Examples of these nano-based carrier systems include:

- * Polymeric nanoparticles
- * Liposomes
- * Dendrimers
- * Polymeric micelles
- * Polymer-drug conjugates
- * Antibody-drug conjugates

These systems can be classified into several categories:

- * Sustained and Controlled Release Systems: Designed to release the drug over an extended period.
- * Stimuli-Responsive Delivery Systems: Release the drug in response to specific internal or external stimuli (e.g., pH, temperature, enzymes).
- * Functional Systems: Designed for the targeted delivery of bioactive agents.
- * Multifunctional Systems: Integrate multiple functionalities, such as drug delivery, biosensing, and diagnostics.
- * Site-Specific Targeting Systems: Designed to deliver drugs to specific intracellular, cellular, or tissue targets(20) (21)

The Carrier Systems are widely Used in the given Regions

7.2.1Cancer treatment

Nanotechnology has revolutionized the landscape of cancer diagnosis and therapy. Traditional cancer treatments, such as radiation therapy, immunotherapy, chemotherapy, and surgery, can be significantly enhanced by the use of nanotechnology-based tools.

- * Carbon Nanotubes: Employed in DNA mutation detection and the detection of disease protein biomarkers.
- * Dendrimers: Utilized for controlled drug delivery and as image contrast agents.

Two major challenges in cancer treatment are:

- * Localized Delivery: Delivering the therapeutic agent specifically to the tumour site.
- * Targeted Therapy: Ensuring that the therapeutic agent selectively targets cancer cells while minimizing damage to healthy tissues.

Cancer treatment strategies often exploit the unique pathophysiology of tumours, such as the presence of leaky vasculature in cancerous tissues.

The use of nanocarriers can significantly alter the pharmacokinetic and biodistribution properties of anticancer drugs.

Nanotools play a crucial role in:

- * Thermotherapy:
- * Photothermal Therapy: Utilizing silica nanoparticles, carbon nanotubes.
- * Magnetic Field-Induced Hyperthermia: Employing magnetic nanoparticles.
- * Photodynamic Therapy: Utilizing quantum dots.
- * Chemotherapy: Utilizing nanostructured polymer nanoparticles, dendrimers, and Nano shells.
- * Radiotherapy: Utilizing carbon nanotubes and dendrimers.

Nanotools achieve these therapeutic effects by:

- * Targeting biomarkers: Identifying and interacting with specific molecules on the surface of cancer cells.
- * Detecting mutations: Identifying genetic alterations within cancer cells.

By addressing these challenges, nanotechnology-based approaches offer promising avenues for improving the efficacy and safety of cancer treatment(23) (24).

7.2.2 Implantable delivery systems

Due to their small size and ability to exhibit controlled, near-zero-order release kinetics, nanoparticles can function effectively as implantable drug delivery systems. This controlled release minimizes the risk of harmful peak plasma concentrations and adverse effects.

Examples of implantable carriers include:

- * Ectospheres: Extracellular vesicles released by cells.
- * Transfersomes: Flexible liposomes capable of deforming to penetrate tissues.
- * Stealth Liposomes: Liposomes modified to evade immune system recognition.

These systems offer several advantages:

- * Reduced risk of adverse reactions
- * Lower peak plasma levels
- * More predictable and extended drug action
- * Decreased frequency of re-dosing
- * Improved patient acceptance and compliance(25).

7.2.3 Gene therapy:

Gene therapy involves introducing a functional gene into a patient's cells to replace a defective gene responsible for a disease.

Nanomaterials, such as chitosan, gelatine, poly-L-lysine, and modified silica nanoparticles, are utilized as gene delivery vectors. These nanomaterials exhibit:

- * Reduced cytotoxicity
- * Enhanced transfection efficiency (the ability to deliver genetic material into cells)

Nanotechnology provides an ideal platform for developing efficient and safe gene delivery vectors(26).

7.3 Biosensor and bio-labels

Biosensors are analytical devices used to detect and quantify various biological or chemical substances. They typically consist of:

- * A biological recognition element: Such as an enzyme, antibody, or nucleic acid, that interacts specifically with the target analyte.
- * A transducer: Converts the biological interaction into a measurable signal (e.g., electrical, optical, or electrochemical).
- * A detector: Measures the signal generated by the transducer.

Nano sensors are biosensors with dimensions on the nanometre scale.

Applications of biosensors and bio labels include:

- * Target identification and validation
- * Assay development
- * Assessment of absorption, distribution, metabolism, and excretion (ADME)
- * Toxicity assessment(27).

7.4 Nanoparticles for oral delivery of peptides and proteins

Significant advancements in biochemistry and biotechnology have led to the discovery of numerous bioactive compounds and vaccines based on peptides and proteins. However, the bioavailability of these compounds is severely limited by the epithelial barriers of the gastrointestinal tract and their susceptibility to degradation by digestive enzymes. This necessitates the development of suitable carriers to overcome these challenges.

One promising approach involves encapsulating bioactive molecules within polymeric nanoparticles. These nanoparticles act as protective shields, safeguarding the encapsulated compounds from hydrolytic and enzymatic degradation. For instance, studies have demonstrated that insulin-loaded nanoparticles effectively maintain insulin activity and lower blood glucose levels in diabetic rats for up to 14 days following oral administration [61].

Furthermore, the vast surface area of human mucosa, which is approximately 200 times greater than that of skin [28], presents a significant opportunity for drug delivery(28).

7.5 Drug discovery

Nanotechnology plays a crucial role in drug discovery. Single-walled nanotubes have been successfully employed to identify pathogen surface proteins. Quantum dots enable the tracking of individual glycine receptors and the evaluation of their dynamics within the neuronal membrane of living cells, with temporal resolution ranging from milliseconds to minutes. Gold nanoparticles and nanobodies (the smallest available, intact antigen-antibody fragments) are commonly used nanomaterials in diagnostic applications. The utilization of nanotechnology facilitates target identification and validation by enabling the precise identification of proteins present on the surface of targets.

Conclusion: We provided a thorough overview of NPs in this paper, including their kinds, synthesis, characterisations, physiochemical characteristics, and applications. It was discovered that NPs range in size from a few nanometres to 500 nm using various characterisation techniques like SEM, TEM, and XRD. However, the morphology can be controlled. NPs are a good contender for a variety of applications because of their huge surface area and small size. In addition, these materials' optical qualities are prominent at that size, which highlights their significance for photocatalytic applications. Controlling the precise size, shape, and magnetic characteristics of NPs can be accomplished with the help of synthetic methods. There are still some health risks associated with NPs despite their numerous applications because of their unregulated use and discharge to the environment, which must be considered in order to make using NPs more practical and environmentally beneficial. In areas where more traditional and established technologies may be reaching their limits, pharmaceutical nanotechnology offers chances to develop new technologies and enhance materials and medical equipment. By offering new patentable technology in response to income loss from off-patent medications, it gives industry new hope.

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