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Original Article

Nanomedicine Drug Delivery System

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ABSTRACT

Nanomedicine and Nano delivery systems are a relatively new but rapidly developing science where materials in the nanoscale range are employed to serve as means of diagnostic tools or to deliver therapeutic agents to specific targeted sites in a controlled manner. Nanotechnology offers multiple benefits in treating chronic human diseases by site-specific, and target-oriented delivery of precise medicines. Drug delivery to certain target cells is now available by using nanoparticles via nanotechnology, Biomedical nanomaterials are used in vivo and in vitro in the clinical researches, because of its large similarities in size and structure to many biological molecules. This aids in the integral of nanomaterials with biology, which end up with the development of diagnostic procedures, contrast agents, analytical tools, and techniques for physical therapy and vehicles for delivery of drugs. However, it is important to understand the interactions of nanomaterials with the biological environment, targeting cell-surface receptors, drug release, multiple drug administration, and the stability of therapeutic agents under research.

Keywords: Nanomedicine; Drug; Disease; Nanotechnology; Environment.

INTRODUCTION

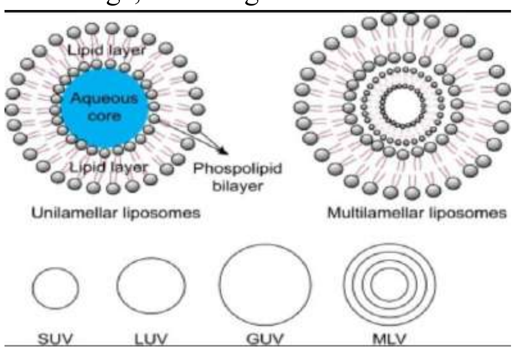
- Nanomedicine is an innovative field that applies nanotechnology to enhance drug delivery systems, improving the efficacy and safety of therapeutics.
- By manipulating materials at the nanoscale (typically 1 to 100 nanometers), researchers can create carriers that facilitate targeted delivery of drugs, minimizing side effects and increasing treatment precision.
- In the relatively new fields of nanomedicine and nano delivery systems, materials in the nanoscale range are employed as diagnostic tools or to administer therapeutic substances to specific targeted areas in a controlled manner.
- Approximately 25% of the primary medicinal chemicals and their derivatives that are now on the market come from natural sources.
- Natural substances with various molecular origins provide a starting point for the development of new medications.
- These nanocarriers can be designed to respond to specific biological triggers, such as pH changes or the presence of particular biomarkers, allowing for controlled release of drugs directly at the site of action.
- This approach not only improves the bioavailability of drugs but also enables the combination of multiple therapies in a single system.
- They are used to cure almost all the disease and abnormalities and helped mankind to fight against infectious diseases and epidemics.
- In Spite of all these significance modern drug dosage forms are facing the problem of its efficacy, bioavailability, toxicity, biocompatibility, side-effects, inactivity are which hinders the drug development and delivery process

CLASSIFICATION:

1. Based on Nanocarrier Type:

A) Liposomes: Spherical vesicles made of lipid bilayers that encapsulate drugs, enhancing solubility and stability.

B) Nanoparticles: Solid particles in the nanoscale range, including:



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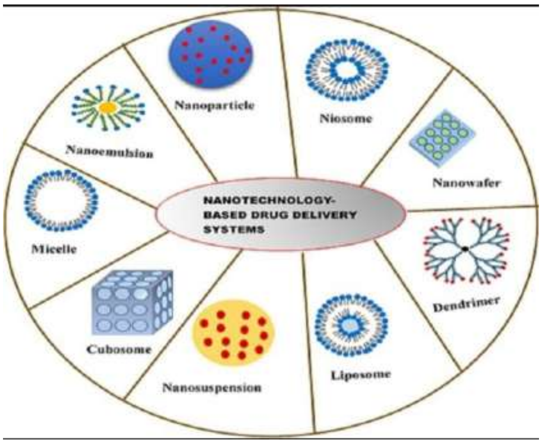


1) **Polymeric Nanoparticles:** Made from biodegradable polymers, used for controlled release.

2) **Metal Nanoparticles:** Such as gold or silver nanoparticles, often used for imaging and therapy.

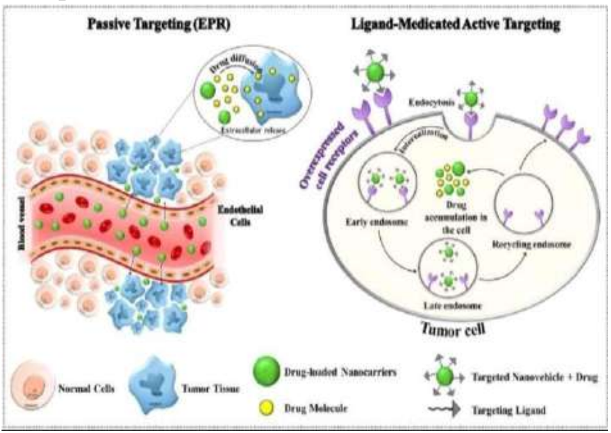
3) **Dendrimers:** Branched macromolecules that provide a high surface area for drug attachment and targeted delivery.

4) **Micelles:** Formed from amphiphilic surfactants, useful for solubilizing hydrophobic drugs.

5) **Nanospheres and Nano capsules:** Different structures used for sustained release of drugs.

2. Based on Drug Release Mechanism:

A) **Passive Targeting:** Utilizes the enhanced permeability and retention (EPR) effect, allowing nanoparticles to accumulate in tumor tissues.



B) **Active Targeting:** Involves functionalizing nanocarriers with ligands that bind to specific receptors on target cells, enhancing selectivity.

C) **Triggered Release:** Employs external stimuli (e.g., pH, temperature, ultrasound) to control drug release at the desired site.

3. Based on Therapeutic Application:

A) **Cancer Therapy:** Targeted delivery of chemotherapeutics, gene therapy, and photothermal therapy.

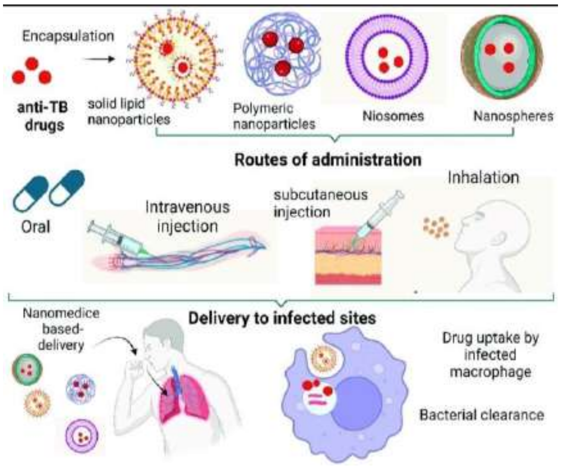
1) **Gene Delivery:** Transporting nucleic acids (DNA, RNA) into cells for genetic modification or therapy.

2) **Vaccine Delivery:** Enhancing the immune response by delivering antigens in a targeted manner.

3) **Antibiotic Delivery:** Improving the efficacy of antibiotics against resistant bacterial strains.

4. Based on Route of Administration:

A) **Oral Delivery:** Nanocarriers designed for effective absorption in the gastrointestinal tract.



B) **Intravenous Delivery:** Direct delivery into the bloodstream for systemic effects.

C) **Topical Delivery:** Formulations for localized treatment, such as in dermatological applications.

D) **Inhalation Delivery:** Nanoparticles designed for respiratory diseases, enhancing drug deposition in the lungs.

TYPES:

1. Nanoparticles

A) **Polymeric Nanoparticles:** Biodegradable polymers are used to encapsulate drugs, allowing for controlled release and improved stability.

B) **Metal Nanoparticles:** Gold, silver, and other metal nanoparticles can be used for targeted delivery, imaging, and photothermal therapy.

C) **Liposomes:** Spherical vesicles made of lipid bilayers that enhance drug solubility and target specific tissues.

2. Dendrimers

Highly branched, tree-like macromolecules that can encapsulate drugs and provide precise control over release and targeting due to their unique surface chemistry.

3. Micelles

Formed from amphiphilic surfactants, micelles solubilize hydrophobic drugs and improve their bioavailability. They can also provide controlled release.

4. Nanospheres and Nano capsules

- **A) Nanospheres:** Solid particles that provide sustained release of drugs.
- **B) Nano capsules:** Hollow particles that encapsulate drugs, allowing for controlled release based on environmental triggers.

5. Hydrogels

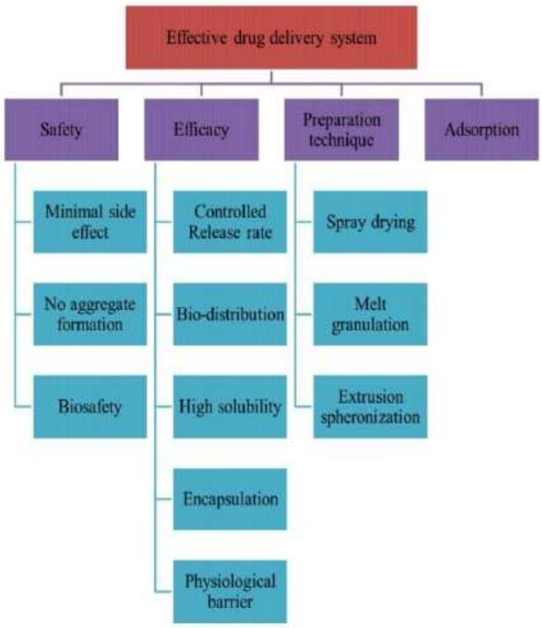
Three-dimensional networks that swell in water and can encapsulate drugs, offering sustained release and responsive behavior to environmental changes (e.g., pH, temperature).

6. Targeted Delivery Systems

A) **Active Targeting:** Nanocarriers are modified with ligands (e.g., antibodies, peptides) that specifically bind to target cells or tissues.

B) **Passive Targeting:** Exploiting the EPR effect, where nanoparticles accumulate in tumor tissues due to leaky vasculature.

- **Mechanism of targeted drug release**



7. Stimuli-Responsive Systems

Nanocarriers designed to release their payload in response to specific stimuli such as pH changes, light, or temperature, allowing for on-demand drug delivery.

8. Combination Therapy Systems

Nanomedicine can facilitate the co-delivery of multiple drugs or therapeutic agents (e.g., chemotherapy and immunotherapy) to enhance therapeutic efficacy.

Application Nanomedicine and drug delivery systems

1. Targeted drug delivery

Nanomaterials can deliver drugs to specific sites in the body, increasing the concentration of the drug in the target area while minimizing side effects. This can be used to treat chronic diseases like cancer, asthma, hypertension, HIV, and diabetes.

2. Improved drug stability and solubility

Nanomaterials can increase the stability and water solubility of drugs, which can improve their safety and effectiveness.

3. Increased oral bioavailability

Nanomaterials can increase the oral bioavailability of drugs by using specialized uptake mechanisms.

4. Reduced enzyme degradation

Nanomaterials can reduce enzyme degradation, which can improve the safety and effectiveness of drugs.

5. Diagnostic tools

Nanomaterials can be used as diagnostic tools to selectively diagnose diseases through disease marker molecules.

6. Precision medicine

Nanomaterials can be developed for specific patient populations, which can increase the efficacy of precision medicines.

Challenges and Opportunities:

Novel drug delivery systems (DDS) have many challenges and opportunities, including:

1) Bioavailability

Poor water solubility and the hostile gastrointestinal environment can make it difficult for drugs to be absorbed and bioavailable.

2) Targeted delivery

It can be difficult to design a carrier system that can target a specific site and release drugs continuously over a set period of time.

3) Physicochemical barriers

These include the high molecular weight of therapeutic proteins and peptides.

4) Biological barriers

These include systemic drug distribution issues.

5) Extracellular vesicles

While exosomes have many advantages, challenges include extraction, separation efficiency, and heterogeneity.

6) Solid tumors

High tumor interstitial fluid pressure (TIFP) can prevent anticancer drugs from reaching tumor cells

7) Imaging:

Imaging techniques like MRI, CT, PET, and ultrasound can help analyze blood vessels and tumors.

8) Nanotechnology: Nanotechnology-based drug delivery systems can be minimally invasive or non-invasive.

9) Technical challenges:

The fabrication process for oral delivery devices can be difficult. *** Some opportunities for novel drug delivery systems include**

1) Self-emulsifying drug delivery systems (SEDDS):

These can improve the oral bioavailability of poorly water-soluble drugs.

2) Nanomedicine and microfabricated devices:

These can help with bioavailability issues.

3) Targeted delivery:

Strategies that focus on site-specific release could improve delivery options.

4) Artificial extracellular vesicles:

These can be mass-produced, are sterile, and are easy to regulate.

5) Materials science:

Enhanced excipients and polymers can help improve drug delivery.

6) Predictive in silico science:

Models and platforms can help predict individual molecule characteristics.

RECENT DEVELOPMENTS

1) Conventional dosage forms

- To minimize drug degradation and loss, to prevent harmful side-effects and to increase drug bioavailability and the fraction of the drug accumulated in the required zone
- Various drug delivery and drug targeting systems are currently under development Novel drug delivery system is a new approach to drug delivery.
- It helps the drug to act longer and more effectively.
- This overcomes limitations of old methods of drug administration Drawbacks of conventional dosage forms.

*** Conventional dosage forms possess following limitations**

a) Poor patient compliance, increased chances of missing the dose of a drug with short half-life for which frequent administration is necessary.

b) The unavoidable fluctuations of drug concentration may lead to under medication or over medication.

c) A typical peak-valley plasma concentration time profile is obtained which makes attainment of steady-state the condition is difficult.

d) The fluctuations in drug levels may lead to precipitation of adverse effects especially of a drug with small therapeutic index whenever over medication occurs.

2) Novel Drug Delivery Systems

In novel drug delivery technology control of the distribution of drug is achieved by incorporating the drug in carrier system or in changing the structure of the drug at molecular level.

*** Novel drug delivery systems possess following Advantages**

a) Enhancement of solubility.
b) Increased bioavailability.
c) Protection from toxicity.
d) Enhancement of pharmacological activity.
e) Enhancement of stability.
f) Improved tissue macrophages distribution.
g) Sustained delivery.
h) Protection from physical and chemical degradation.

3) Herbal drugs

- Herbal formulation means a dosage form consisting of one or more herbs or processed herb(s) in specified quantities
- to provide specific nutritional, cosmetic benefits, and/or other benefits meant for use to diagnose treat, mitigate

- Diseases of human beings or animals and/or to alter the structure or physiology of human beings or animals.
- Herbal preparations are obtained by subjecting whole plants, fragmented or cut plants, and plant parts to treatments such as extraction, distillation, expression, fractionation, purification, concentration or fermentation.
- These include comminuted or powdered herbal substances, tinctures, extracts, essential oils, expressed juices and processed exude

PROPERTIES

- Novel drug delivery systems (DDS) possess several key properties that enhance their effectiveness and safety. These properties include:

1. **Targeted Delivery:** Ability to deliver drugs specifically to the site of action, minimizing systemic exposure and side effects.
2. **Controlled Release:** Systems designed to release drugs at a predetermined rate, allowing for sustained therapeutic effects over time.
3. **Biocompatibility:** Materials used should be compatible with biological tissues, reducing the risk of adverse reactions.
4. **Stability:** The formulation must maintain stability over time, ensuring that the drug retains its efficacy and safety until administration.
5. **Enhanced Solubility:** Improved solubility of poorly water-soluble drugs, increasing their bioavailability and effectiveness.
6. **Biodegradability:** Use of materials that can break down into non-toxic byproducts, reducing long-term environmental impact and the need for surgical removal.
7. **Ease of Administration:** User-friendly methods of delivery (oral, injectable, transdermal, etc.) that improve patient compliance.
8. **Scalability:** Ability to be produced at various scales without compromising quality or efficacy.
9. **Multi-functionality:** Capability to combine therapeutic agents, diagnostic tools, or imaging agents in a single delivery system.
10. **Responsive Mechanisms:** Systems that respond to specific stimuli (e.g., pH, temperature, or biological markers) to release drugs only when needed.

ADVANTAGES OF NANOTECHNOLOGY

1. **Improved materials:** Nanotechnology can make materials stronger, lighter, more durable, and more reactive.
2. **Miniaturization:** Nanotechnology has made it possible to miniaturize electronic devices.
3. **Energy efficiency:** Nanotechnology has improved energy efficiency in many sectors. It can also be used to generate and store energy, and to make renewable energy devices.
4. **Environmental benefits:** Nanotechnology can reduce the demand for material resources, increase thermal properties, and remove pollutants from the environment.
5. **Construction:** Nanotechnology can improve the durability, strength, and life span of construction materials.
6. **Crop protection:** Nanotechnology can help protect crops from toxic chemicals and detect plant diseases. It can also reduce post-harvest losses.
7. **Aerospace:** Nanotechnology can help manufacturers develop aircraft that are stronger and lighter, which improves their performance.
8. **Medical innovations:** Nanotechnology could change how diseases are prevented and treated.
9. **Computing and electronics:** Nanotechnology have led to significant innovations in computing and electronics.
10. **Diagnostic tools:** Nanotechnology has improved access to advanced diagnostic tools.

DISADVANTAGES OF NANOTECHNOLOGY

1. Health risks: nanoparticles can be harmful to human health if inhaled or if they penetrate cells and tissues. Inhaled nanoparticles can cause lung inflammation and heart problems.

2. Environmental risks

Nanomaterials can contaminate soil and water, and can harm plants and animals.

3. Economic impact

Nanotechnology research and development can be expensive, which may limit the ability of smaller businesses to participate.

4. Social impact

Nanotechnology may lead to job loss in traditional manufacturing and farming, and may threaten privacy.

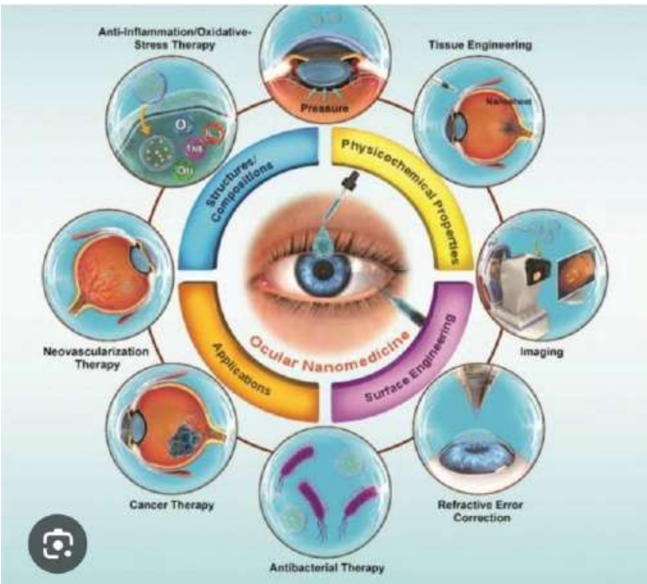
5. Ethical concerns

Some oppose the use of nanotechnology to create lethal autonomous weapons. There is also a fear that nanotechnology could self-replicate, creating a "gray goo" scenario.

6. Lack of regulations

There are few regulations governing the development and use of nanotechnology, which could lead to risks being overlooked.

Current status and Future prospects



- The exploration of a novel drug delivery system (NDDS) has been ongoing for many years but it has gained much traction in recent centuries.
- The motive for the development of NDDS has been two-fold.
- First, there are the obvious clinical benefits of these systems, followed by their economic implications.
- The NDDS have been developed and are being developed to gain greater control over a drug's pharmacokinetics and pharmacodynamics after administration, resulting in dosage forms that are extremely effective, safe, and superior to traditional products.
- Reformulation of old medicine in an NDDS frequently revives clinical interest in the drug, extending its effective market life.
- In India, the pharma business is worth ~Rs. 20 000 crores, of which ~5% is the NDDS market, at Rs. 1000 crore.
- This difference between the Indian and worldwide markets implies that the NDDS industry in India has enormous potential.
- India serves as an important market for the pharmaceutical industry.
- Therefore, many multinational companies have been anxious to invest and grow preferentially in this sector.
- The future of novel drug delivery systems (DDS) is poised for significant advancements driven by technological innovations and a deeper understanding of biology. Key prospects include:

1. **Nanotechnology:** The use of nanoparticles for targeted drug delivery can enhance therapeutic efficacy and minimize side effects. Nanocarriers can be designed to release drugs at specific sites, improving treatment outcomes for diseases like cancer.
2. **Smart Drug Delivery Systems:** Incorporating stimuli-responsive materials that release drugs in response to specific biological triggers (pH, temperature, or enzymes) can lead to more effective treatments tailored to individual patient needs.
3. **Biologics and Biosimilars:** Advances in the delivery of biologics, including monoclonal antibodies and gene therapies, will facilitate more effective treatments for various conditions, including genetic disorders.
4. **Personalized Medicine:** Tailoring drug delivery systems based on genetic, phenotypic, and lifestyle factors will enhance treatment effectiveness and reduce adverse effects, allowing for more customized therapeutic strategies.
5. **3D Printing:** This technology can revolutionize drug formulation and delivery, allowing for the production of patient-specific dosage forms and complex drug delivery systems.
6. **Micro- and Nanofluidics:** These technologies can facilitate precise control over drug delivery processes, enabling real-time monitoring and adjustment of therapeutic strategies.
7. **Wearable Devices:** Integration of drug delivery systems with wearable technology can enable continuous monitoring and administration of medications, improving patient adherence and outcomes.
8. **Regenerative Medicine:** Advanced delivery systems for stem cells and growth factors can enhance tissue regeneration and repair, offering new therapies for chronic conditions and injuries.

- Numerous advancements in the field of nanomedicine demonstrate its significance for clinical and other medical aspects.

- Numerous researchers have looked into the role that nanomedicine plays in treating cancer and lowering rates of morbidity and mortality.

CONCLUSION

According to the conclusions of this study, nanomedicine and drug delivery systems play an essential role in the pharmaceutical sector. It may be used to treat renal issues, and it is also used in the current Covid-19 immunization treatments. The technique is also essential in the treatment of cancers and other disorders. However, there are potential risks linked with nanomedicine and nanotechnology in general. The advancement of nanotechnology may result in the value of gasoline and diamonds falling, owing to the prospect of creating alternative energy sources that are more effective and do not need the combustion of fossil fuels. Eventually, atomic weapons may become more readily available and more potent and devastating. Therefore, as much as nanomedicine, nanotechnology, and drug delivery system may be beneficial, great care is paramount to ensure that their application is for good purposes. Nanoparticles are rapidly becoming the focus of most efforts aiming at targets and site-specific drug delivery. The targeting ability of nanoparticles depends on certain factors such as particle size, surface charge, surface modification and hydrophobicity. Still many problems related to selective binding, targeted delivery and toxicity need to be overcome. Limited knowledge about the toxicity of nano- particles is a major concern and certainly deserves more attention. If these nanoparticles are cautiously designed to tackle problems related to target and route of administration, they may lead to a new more successful paradigm in the world of therapeutics and research. The most promising research in nanoparticle production is via using supercritical fluids which are environmentally friendly and free of toxic solvents. Much research is currently being performed to overcome these hurdles which will definitely establish nanoparticle-based drug delivery as the gold standard for site-specific therapeutics.

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