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Review Article

Nanotechnology in Drug Delivery System: A New Approach

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Abstract

An extensive examination of the prior developments of drug delivery systems (DDS) based on nanoparticles will be covered in this study, along with novel research findings on the therapeutic improvement of antiretroviral therapy. Practitioners will be able to provide medications to target particular body parts thanks to the use of nanoparticle DDS. The application of nanoparticles as a DDS is having a discernible therapeutic impact in the treatment of cancers. DDS will also be used in medical imaging to illuminate brain function, cancers, or other body cellular activities. There is great promise for using nanoparticle DDS to enhance human health. Its unique features, such as its nanoscale structure, improved permeability and retention capacity, higher surface-area-to-volume ratio, ability to be functionalized on the surface etc., make it a successful drug delivery method for the administration of antiviral treatments. The more important variables that impact target-specific drug delivery, optimal cellular uptake, degree of opsonization by host immune cells, drug retention time, transcytosis, biological half-life extension, in vivo stability, and cytotoxicity are nevertheless the size, shape, charge, and surface topology of the nanoparticles. The review will shed light on the significant obstacle of clinical safety and efficacy as well as the elaborate role of drug delivery based on nanotechnology.

Keywords: Nanotechnology, Dendrimers, Controlled drug release, Nanoparticle, Nanospheres.

Introduction

Nanoscience is the only platform to discover the new properties of matter by collaborating with conventional fields such as applied health, molecular chemistry, molecular science, pharmaceutical science, optics, and even engineering. In recent decades, science and technology have frequently been well-architected to address the challenges in the medical and health sciences by offering therapeutic approaches, nano-medical equipment, and a more efficient health system. In the past, Professor N. Taniguchi was the first to use the word "nanotechnology" in 1974. Drexler quickly created and published the first nanotechnology concept (Feynman's concepts) in his 1986 book "Vehicles of Creation: The Coming of the Nanotechnology Era"[1].

The effects of nanotechnology on humans and animals are currently opening up new research directions and transforming health science, making it a crucial topic for therapeutic tool consideration. By developing new devices and characterizing material structure technologies with special properties, nanotechnology, a very shady multidisciplinary field, was created to engineer biological matters like atoms, molecules, and supramolecules at the nanoscale range of about 1 to 100 nm. This holds promise against current challenges by studying and comprehending deadly biological problems, followed by the diagnosis and treatment of disease[2,3]. The most prevalent and widely used technology of the past few decades is nanotechnology, which is also extremely important to human life. Notably, the components of living cells are incredibly important pieces of equipment that are minuscule (nanoscale). They have a strong role in practically every biological process, such as metabolism, energy production, cell signalling, and nutrient transport. In order to address biology and medicine for therapeutic objectives, nanotechnology might be considered a crucial candidate that can provide new technologies at the individual matter level[4]. The development of numerous nanoscale materials with numerous therapeutic benefits has led to the rise of nano-medicine as the gold standard in the health sciences[5,6].There are many benefits of generating and distributing various nanomedicine products through the pathophysiological and clinically linked regulation of diseased/abnormal tissues/cells. Therefore, there may be a variety of strategies to improve the prognosis of the disease using

tissue-specific medication targeting techniques[7]. In the varied field of medical science, nanomaterials more specifically, metal nanoparticles have drawn more attention in recent years. Nowadays, a lot of research is being done on how to best synthesize nanomaterials such polymers, micelles, dendrimers, liposomes, emulsions, nanocapsules, and nanoparticles. One of the most prominent uses of nanotechnology today is nanomedicine, which is dedicated to creating nanoscale medical instruments to support an efficient healthcare system. This method enables us to better understand human physiology in order to combat a number of fatal illnesses, including cancer and cardiovascular ailments. In order to precisely deliver drugs to target sites and improve treatment outcomes by lowering toxicities and off-target effects, nanomedicine is primarily used for imaging, disease diagnosis, tissue engineering, and designing more effective, affordable, and safe drug delivery systems[8].The use of nanoscale instruments and materials to identify, treat, and prevent illnesses is known as nanotechnology in medicine. This approach frequently makes tailored medication delivery and sophisticated diagnostic imaging possible. For instance, in medicine, any size smaller than a micrometer is referred to as nanometric; this dimension can be used to regulate the body's drug distribution or the interactions between implants and tissue[9].

History of Nanotechnology

One of the most important technologies of the twenty-first century is nanotechnology. It goes without saying that the creation and application of the smallest particles that are invisible to the human eye are not modern innovations. The famed Damascene Swords, several late medieval church windows, and the Lycurgus Cup from the fourth century AD on display at the British Museum in London are a few examples of the earlier employment of nanomaterials. The ancient Roman cup appears olive green when illuminated from the outside but turns purple when illuminated from the inside, revealing a legendary ruler. This phenomenon is caused by colloidal nanoparticles of gold and silver that are present in the glass. Some late medieval church windows have a similar effect, shining a dazzling red and yellow due to the fusion of gold and silver nanoparticles into the glass. A 17th-century Damascene blade was found to contain nanometer-sized carbon particles in 2006; these particles are what give the fabled swords their flexibility and resilience[10]. In 1902, Richard Zsigmondy and Henry Siedentopf's ultramicroscope was used to successfully discern features in ruby glasses that were smaller than 4 nanometers[11]. Zsigmondy submitted a patent application for the immersion ultramicroscope in 1912, which made it feasible to study the behaviour of colloidal solutions. The transmission electron microscope (TEM), created by Max Knoll and Ernst Ruska, began to reach noticeably higher resolutions in 1931 than the light microscopes that had been in use until that time[12]. In his 1959 paper 'There is Plenty of Room at the Bottom', physicist and Nobel laureate Richard P. Feynman foresaw the emergence of nanotechnologies and the opportunities that would come with them. A call to explore a new area of physics. Furthermore, this paper is considered the foundational text of nanotechnology, despite the fact that the word "nano" does not appear once in it. In addition to predicting that the development of more accurate microscopes will allow access to the field of individual atoms and that it would be possible to arrange atoms as desired, Feynman challenged us to think about the creation and control of microscopic devices based on quantum mechanics[13]. In the first and most contentious book on nanotechnology, "The Coming Era of Nanotechnology", author K. Eric Drexler explained how to build complex machines out of individual atoms that can independently manipulate molecules and atoms to produce things and replicate themselves[14]. In their book Unbounding the Future, K. Eric Drexler, Chris Peterson, and Gayle Pergamit outline the potential use of such "nanobots" or "assemblers" in the medical field. The phrase "nanomedicine" was allegedly first used in 'The Nanotechnology Revolution', which was published in 1991[15]. With the publication of Robert A. Freitas' book Nanomedicine in 1999, the term gained popularity and has been used in technical writing ever since. Since Feynman and Drexler's vision of nanoscale robots that patrol the body, neutralize disease foci, and identify and repair organs and cells with impaired function is still a way off, nanomedicine focuses on investigating the potential for controlling and modifying cell processes, such as by delivering active substances to specific locations[16].

Paul Ehrlich made an effort at the start of the 20th century to create 'magic bullets' that could be used to target diseases and eradicate all germs with just one treatment. He created Salvarsan, which is considered to be the first precisely acting medication of this kind and the precursor to chemotherapy. Production of increasingly complex 'magic bullets' was made possible by the 20th century's discoveries about cells and their components, intracellular and intercellular activities, and cell communication, as well as developments in biochemistry and biotechnology[17]. Currently, biocompatible polymers, liposomes, and micelles are being studied as medication, vaccine, and gene carriers. Nanomaterials can circulate within the body until they reach their target because of their small size (often less than 200 nm), which prevents them from being filtered out of the blood[18].

Advantages of Nanotechnology:

1. Targeted Drug Delivery: Active targeting is when the drug carrier system is conjugated to a tissue or cell-specific ligand, while passive targeting is when nanoparticle reaches the target organ due to the leaky junctions[19].
2. Improved bioavailability by enhancing aqueous solubility[20].
3. Increasing resistance time in the body (increasing half-life for clearance/increasing specificity for its cognate receptors)[21].
4. Improved therapeutic effects and drug solubility improved therapeutic effects and drug solubility[22].

Disadvantages of Nanotechnology:

1. Toxicity: Nanoparticles can have unexpected toxic effects on cells, including damage to DNA, proteins, and lipids[23].
2. Drug resistance: Nanoparticles can help deliver chemotherapy drugs to tumors, but tumor cells can develop resistance to these drugs over time[24].
3. Oxidative stress: Inhaled nanoparticles can cause oxidative stress[25].
4. Inflammation: Inhaled nanoparticles can cause inflammation in the lungs[26].

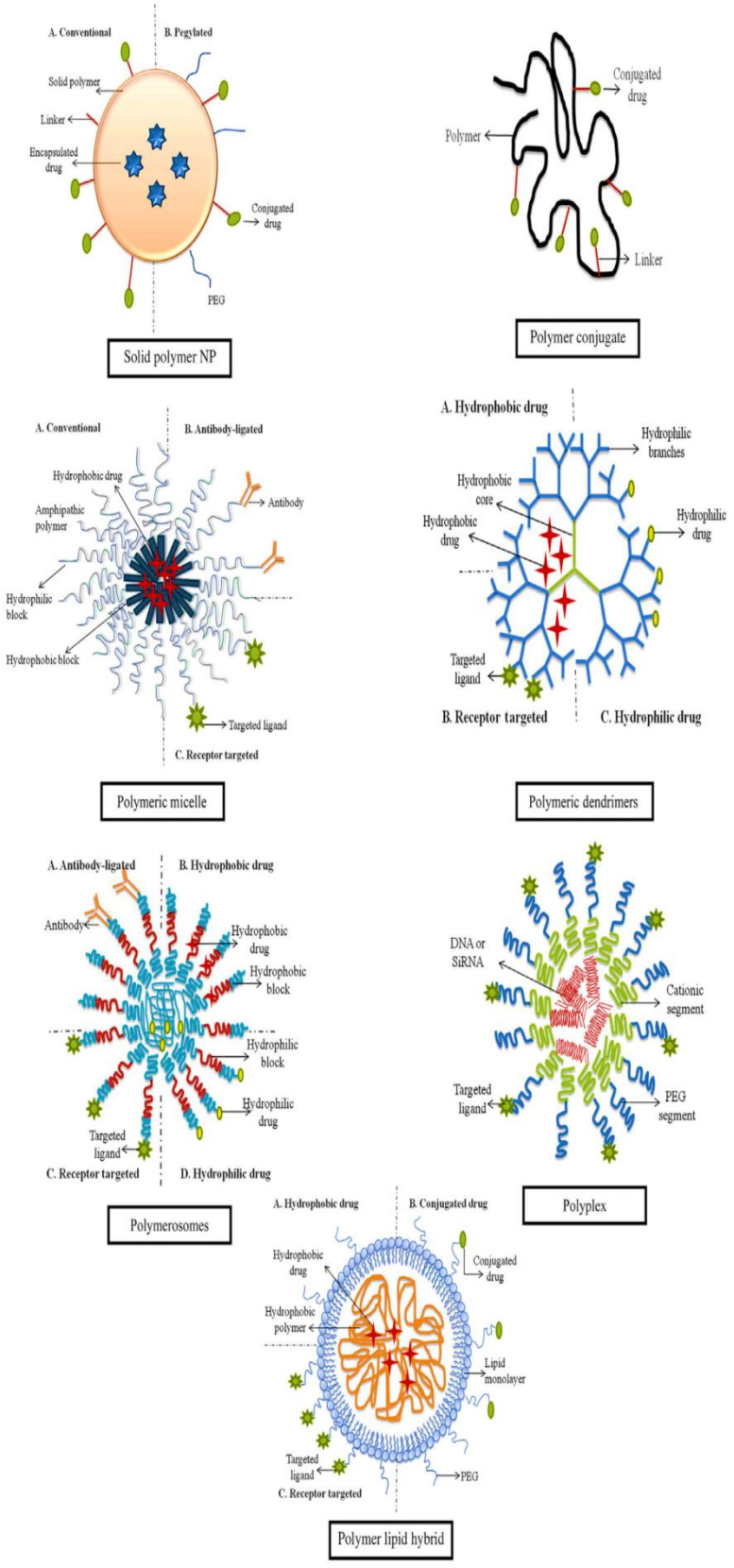

FIGURE.1: The composition of polymer nanocarrier platforms with their drug-loading methods[27]

Polymeric Nanocarriers:

1. **Solid polymeric nanoparticles**

The therapeutic drug is dissolved, entrapped, encapsulated, or adsorbed into the constituent polymer matrix of solid polymeric nanoparticles (NPs), which are solid colloidal systems[28].For focused medication delivery, several solid polymeric nanoparticles have been created. As an illustration, consider the PEGylated poly(lactic-co-glycolic acid) (PEG–PLGA) NP loaded with paclitaxel (PTX), which produced a better lethal effect on liver tumour growth both in vitro and in vivo as compared to the free drug[29].

2. **Polymeric micelle nanoparticles**

Polymeric micelle nanoparticles have a hydrophobic core and a spherical, amphiphilic, self-assembling core or shell shape that facilitates drug encapsulation. Polymeric micelles have demonstrated remarkable drug-carrying capacity in oncotherapy[30]. Research by Jin et al. to determine the impact of PTX-loaded N-octyl-O-sulphate chitosan micelles on the treatment of multidrug-resistant malignancy serves as one example. The micelles show strong in vivo tumour inhibition and a two fold increase in cellular absorption compared to the free medicines[31].

3. **Polymeric dendrimers**

The dendrimers are artificial macromolecules that have several extensions extending from the central core, giving them a tree-like structure. Either the dendrimer surface or the core can contain conjugated or encapsulated therapeutic substances[32]. The poly (glycol-succinic acid) dendrimers that carry camptothecin are one instance. When treating human breast cancer (MCF-7), colorectal adenocarcinoma (HT-29), non-small cell lung carcinoma (NCI-H460), and glioblastoma (SF-268), increased drug absorption and cytotoxicity up to 16 and 7-fold, respectively, were reported in comparison with the free drug[33].

4. **Polymersomes**

Synthetic copolymers known as polymersomes self-assemble into distinct hydrophobic and hydrophilic blocks. Polymersomes are more stable, have greater storage capacity, and have a longer circulation time than liposomal NPs, despite this. Polymersome vesicles containing DOX were found to be more effective at suppressing tumour growth in comparison to liposomal NPs[34].

5. **Polyplexes**

Polyplexes are polymer nanocarriers. Through electrostatic interactions, genes or siRNA are bonded to the cationic polymer group in polyplexes. The primary application of polyplexes is in cancer-specific gene therapy. The polymeric vectors based on galactose-modified trimethyl chitosan-cysteine are one example. When evaluated in human lung cancer (A549) and liver cancer (QGY-7703) cells, these polyplexes demonstrated excellent in vitro and in vivo capability of delivering siRNA, leading to effective and long-lasting gene suppression[35].

6. **Polymer-lipid hybrid**

The polymer-lipid hybrid system, which combines liposomes with polymeric NPs. This system consists of a hydrophilic shell with a hydrophobic core, separated by a lipidic monolayer. Wong et al. investigated a system in which a polymer derived from soybean oil was conjugated to DOX and then dispersed with lipid in water. DOX was delivered well, and P-gp-overexpressing human breast cancer cell lines had eight times more cytotoxicity[36].

The therapeutic drug was either encapsulated inside the polymeric core of each of these polymeric nanocarrier types or adhered to the NP surface[37].

Ideal characteristics

To optimize its effectiveness and safety, the perfect nanoscale medication delivery system would have a number of essential characteristics. Among them are:

1. Targeted delivery is the capacity to distribute medications just to the targeted cells or tissues, limiting side effects and minimizing off-target effects[38].
2. Controlled Release: The capacity to gradually and deliberately release the medication over time, maintaining a therapeutic impact and minimizing the need for repeated dosage[39].
3. Biocompatibility: Materials ought to be in harmony with the body and not cause toxicity or an immunological reaction[40].
4. Stability: To guarantee that the medication is effective until it reaches its target, the system must be stable in both biological environments and storage[41].
5. The ideal size, usually in the nanoscale range, and surface features to enable cellular absorption and passage through biological barriers, such as the blood-brain barrier[42].
6. Biodegradability: To avoid building up in tissues, nanoparticles should be able to break down metabolically. Lipids, proteins, and polymers are among the materials frequently employed for this purpose[43].
7. Improved solubility and absorption of medications, especially those with low solubility or low bioavailability when taken orally, is known as enhanced bioavailability[44].
8. Scalability and reproducibility: Easy production at a scale that meets clinical and commercial requirements, as well as consistent quality across batches[45].

Table 1: Types of nanotechnology[46-48]

Type of Nanotechnology	Description	Applications
Nanoparticle	Ultra-small particles (1-100 nm) that can be engineered for various functions.	Drug delivery, imaging, diagnostics, and therapy
Microsphere	Spherical particles that can encapsulate drugs, often used for controlled release over time.	Polymeric microspheres for chemotherapeutic agents
Nanospheres	Spherical nanoparticles with uniform size, often used for drug delivery.	Controlled drug release, imaging, and diagnostics
Nanorods	These are rod-shaped nanoparticles with applications in imaging and therapy.	Cancer treatment, imaging, photothermal therapy
Dendrimers	Branched nanostructures with multiple functional groups for targeted delivery.	Drug delivery, gene delivery, and imaging
Nanocapsules	Nanoparticles that encapsulate drugs or other substances for delivery.	Controlled release of pharmaceuticals

DRUG SELECTION CRITERIA

The five principles for the manufacture of safe nanoparticles serve as the basis for selecting the major and sub-criteria connected to the preparation of calprotectin-loaded polymeric nanoparticles, as well as possible alternatives.

To be more precise, the guiding ideas are as follows:

- Cutting a medicine down to a nanoscale level without affecting how it works.
- Substituting appropriate nontoxic chemicals for the hazardous ones utilized in the preparation.
- Atoms and molecules bonding to nanoparticles without causing toxicity while maintaining the product's intended feature.
- Encasing highly toxic pharmaceuticals in harmless polymers to lower the drug's toxicity.
- When it is not possible to avoid using harmful chemicals, use them in small quantities. There were eight viable approaches or substitutes chosen to create polymeric nanoparticles[49,50].

EXCIPIENTS[51-61]

NADDSs provide particular difficulties in the design and production processes. To achieve nanoscale size and avoid aggregation during processing or storage, a variety of excipients are utilized.

1. POLYMERIC NANO PARTICLES

- Sodium alginate gelatine polylactic acid
- Polyglycolic acid
- Dextran

2. SOLID LIPID NANO PARTICLES

- Tricaprin
- Tristearin
- Glyceryl monostearate
- Cetyl palmitate
- Palmitic acid.

3. EMULSIONS

- Soybean lecithin
- Egg lecithin
- Polaxamer 188
- Polysorbate 80
- Tyloxapol

4. VESICLE BASED SYSTEMS

- Phosphatidylcholine
- Distearoyl
- Dipalmitoyl phosphatidic acid
- Cholesterol

5. STABILIZERS

- Poly vinyl alcohol
- Poly vinyl pyrrolidone (PVP)
- Polyacrylic acid
- Hydroxypropyl methyl cellulose (HPMC)

Methods of Preparation

1. Phase separation

By continuously swirling the mixture into the polymer-drug solvent phase and then extracting the resultant mixture, the phase separation method causes the polymer to separate into drug-containing droplets. In order to quench these micro-droplets, the droplet is dipped into an insoluble media (both organic and aqueous). The droplet's hardness and coarsening characteristics are controlled by the amount of time spent soaking in the quenching bath. For later usage, it is gathered by centrifugation, washing, sieving, filtering, and freeze-drying[62].

2. Nanoprecipitation (solvent displacement/solvent diffusion)

This process shows that the medication and polymer are dissolved in an organic solvent and then moved at a steady pace into an aqueous solution containing surfactants. To fully remove the organic solvent, the resultant colloidal suspension is constantly agitated (800–900 rpm) for 4–5 hours under a fume hood[63].

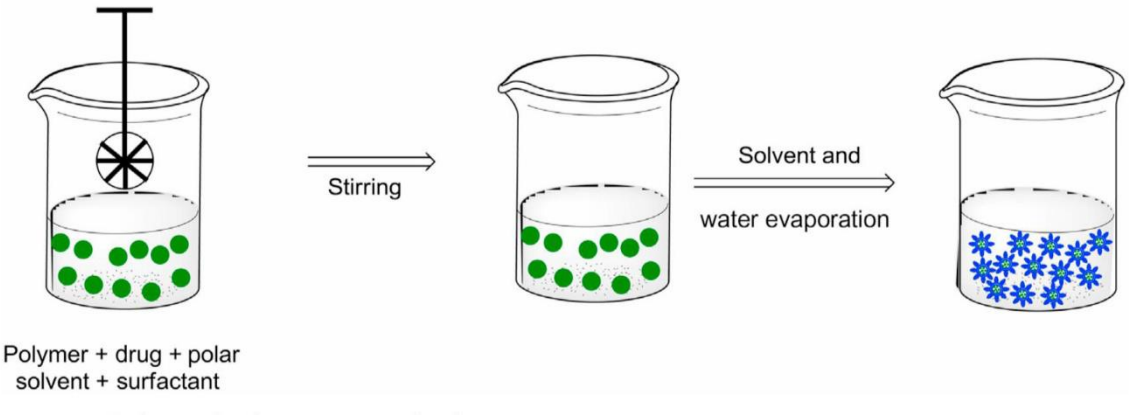

FIGURE.2: Nanoprecipitation Method[63]

3. Supercritical fluid technology

The use of organic solvents, which are hazardous to both the environment and physiological systems, makes conventional procedures risky. Because a supercritical fluid (SCF) technology solvent stays at a temperature above its critical temperature, when fluid departs as a single phase regardless of pressure, SCF technology has been investigated as a safe and alternative method to create biodegradable micro and nanoparticles. Because it is inexpensive, non-flammable, and harmless, supercritical CO_2 is the most widely utilized SCF. A liquid solvent, like methanol, which is completely miscible with the SCF, is used in the supercritical antisolvent process to dissolve the solute that needs to be micronized. The generation of NPs is caused by the solute's rapid precipitation due to its insolubility non SCF[64,65].

4. Dialysis

A straightforward technique for making PNPs is dialysis. The polymer is dissolved in an organic solvent using this technique. After the solvent loses its solubility, it dislocates inside the membrane, allowing a homogeneous suspension of PNPs to form. Dialysis is carried out through the dialysis membrane against a nonsolvent that was miscible with the prior miscible solvent[66].

Evaluation of Nanoparticles

1. Surface Charge (Zeta Potential)

The stability, interactions with biological membranes, and cellular uptake of nanoparticles are all influenced by their surface charge, which can be either positive, negative, or neutral. The Zeta potential of a nanoparticle is typically used to determine the particle's surface charge characteristics. This representation of the particles' electrical potential is affected by both the particles' own structure and the medium in which they are distributed. Since the surface charge inhibits particle agglomeration, nanoparticles need to have zeta potentials higher than 30 mV to remain stable in suspension. For best stability, zeta potential values usually fall between -30 and +30 mV. Evaluation Techniques: Electrophoretic light scattering is used to measure zeta potential[67,68].

2. Drug Loading Capacity and Encapsulation Efficiency

The therapeutic impact depends on how much medication can be placed into a nanoparticle and what proportion of the drug is properly encapsulated without deteriorating or being lost during processing. Evaluation techniques include High-Performance Liquid Chromatography (HPLC) and UV-Visible Spectrophotometry[69].

3. Stability

The shelf-life and efficacy of nanoparticles depend on their physical and chemical stability. Aggregation, medication breakdown, or a reduction in therapeutic action might result from instability. For 90 days, the formulation was stored at 4°C, 1°C, 30°C, and 2°C to test the stability of the produced nanoparticles. The samples were reanalysed after a certain amount of time, such as 0, 1, 2, and 3 months, to determine whether their physical properties, drug content, or drug release rate had changed. Evaluation techniques include freeze-thaw cycling, accelerated stability testing, and storage in various settings[70,71].

4. Immunogenicity

It is important to carefully assess the immune response to the nanoparticles since it may result in unintended side effects or early clearance. Methods of Evaluation: Measurement of cytokine levels, antibody response, and immune cell activity (T-cells, macrophages)[72].

5. Pharmacokinetics and Biodistribution

The absorption, distribution, metabolism, and excretion (ADME) of the drug-nanoparticle combination are all included in the pharmacokinetic profile. Effective drug delivery depends on dispersion, particularly to the target organ or tissue. Methods of evaluation include blood sample for pharmacokinetic modelling, radiolabelled drug formulations, and in vivo imaging[73].

6. Particle Size and Distribution

The capacity of nanoparticles to pass through biological barriers like cell membranes or the blood-brain barrier depends critically on their size. Particles that are smaller (usually between 10 and 200 nm) have better bioavailability and cellular absorption. Photon-correlation spectroscopy, also known as dynamic light scattering, has been demonstrated to be the most reliable and efficient method for determining the sizes of individual particles. Scanning or transmission electron microscopy (SEM or TEM) is frequently used to confirm data generated by photon-correlation spectroscopy. Evaluation techniques include Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), and Dynamic Light Scattering (DLS)[74,75].

7. Drug Content[76]

The amount of medication in the supernatant was then measured using a UV spectrophotometer to create the standard calibration curve. The amount of medication in the supernatant is then subtracted from the total amount needed to create the nanoparticles. The % of drug entrapment as determined by,

% Drug Entrapment = (total drug conc.-total supernatant conc.) /total drug conc. × 100

8. The yield of Nanoparticles[77]

By comparing the total weight of the produced nanoparticles to the total weight of the drug and copolymer combined, the particle yield can be determined.

% Yield = weight of nanoparticle/ weight of polymer and drug fed initially ×100

Applications:

1. Gene Therapy

Gene therapy is the process of replacing a disease-causing broken gene in the DNA with a healthy gene. The gene is usually inserted into the stem cells using a vector. Because stem cells have the ability to self-renew and have a longer lifespan, they are the greatest candidates for gene therapy. Additionally, nanotechnology is essential for delivering genetic materials for gene therapy, including DNA, RNA, and siRNA. Viral vectors, lipid nanoparticles, and dendrimers are examples of nanoparticles that are highly effective at delivering genetic material to target cells. For instance, mRNA-based vaccinations, like the COVID-19 vaccines, use lipid nanoparticles to transfer genetic material into cells[78].

2. Targeted Drug Delivery

Drug toxicity and adverse effects can be decreased by using nanotechnology to create drug delivery systems that can target particular cells, tissues, or organs. For instance, ligands or antibodies that identify and attach to particular receptors that are overexpressed on the surface of cancer cells can be used to functionalize nanoparticles. This minimizes harm to healthy tissues while enabling direct drug delivery to the tumor[79].

3. Nanotechnology in the Treatment of Brain Diseases

If the blood-brain barrier (BBB) issue is fixed, brain disease treatments may be successful. Neural tissues and the bloodstream are separated by the blood-brain barrier in the brain. The blood-brain barrier, which keeps the brain's homeostasis intact and stops drugs from accessing the central nervous system (CNS), is the largest barrier to treating brain disorders. Any disturbance of the blood-brain barrier can result in neuro-inflammatory and neurodegenerative diseases such as Parkinson's disease, Alzheimer's disease, and others, but even a damaged blood-brain barrier makes it impossible for drugs to reach the brain. NPs have been used to treat a variety of conditions since the blood-brain barrier was broken down, such as stroke, Parkinson's disease, Alzheimer's disease, and many more that are discussed here. Drug delivery to the brain is made extremely difficult by biological barriers like the blood-brain barrier, which nanoparticles can be engineered to overcome. To increase their permeability through these barriers, nanocarriers such polymeric nanoparticles, liposomes, and solid lipid nanoparticles can be functionalized. For example, targeting ligand-coated nanoparticles, like transferrin, have been created to deliver medications to the brain[80].

4. Inhalation Therapy

By using nanotechnology to the diagnosis, treatment, and screening of a broad range of diseases, nanomedicine has the potential to fundamentally alter both public and private health. Drugs can be delivered specifically to the lungs through inhalation using nanoparticles. This is especially helpful for conditions including lung cancer, asthma, and chronic obstructive pulmonary disease (COPD). For instance, bronchodilators, corticosteroids, or anticancer medications based on nanoparticles can be inhaled straight into the lungs, improving therapeutic effects and lowering systemic adverse effects[81].

5. Antidiabetic agents

Insulin was combined with a protamine, a cell-penetrating peptide, and then encapsulated in N-trimethyl chitosan chloride-coated mucoadhesive poly(lactic-co-glycolic acid) (PLGA) nanoparticles. The findings indicated that diabetic rats exhibited a quicker onset and a longer-lasting hypoglycemia effect. When compared to subcutaneous insulin injection, the oral delivery system's bioavailability was 17.98 ± 5.61%. It's interesting to note that this oral insulin delivery system has much improved, with greater bioavailability in

experimental animals. This suggests that the cells have better internalised the mucoadhesive NPs than native insulin. Thus, conjugating insulin with cell-penetrating peptides and then encasing it in mucoadhesive nanoparticles may be a helpful way to deliver insulin orally[82].

6. Nanotechnology in Antimicrobial Drug Delivery

The broad-spectrum antibacterial qualities of silver nanoparticles allow them to interfere with cellular processes and damage bacterial cell membranes. Antimicrobial drugs can be delivered more precisely and overcome resistance mechanisms with the help of nanoparticles[83,84].

7. Anticancer agents

Cisplatin is a significant anticancer medication that inhibits DNA synthesis and interferes with cell division through mitosis. The DNA repair mechanism is triggered by damaged DNA. Although cisplatin is a very effective anticancer medication, its full therapeutic potential is restricted because of its toxicity to healthy tissues, which includes nausea, vomiting, and toxicity to the kidneys and ears. Cisplatin's therapeutic index would be improved and medication toxicity would be greatly decreased by tailored delivery to tumor cells[85].

8. Improved Solubility and Bioavailability

A lot of medications have poor solubility, which reduces their bioavailability. Nanoparticles can improve solubility in a number of ways, such as by increasing surface area and decreasing size[86].

9. Combination Therapy:

Multiple medications can be co-delivered by nanoparticles, resulting in synergistic effects that improve treatment effectiveness and lower drug resistance. For instance, paclitaxel and cisplatin co-delivered via nanoparticles for increased anti-cancer efficacy[87].

10. Cosmeceuticals

When employed as vehicles for molecular sunscreens, lipid nanoparticles demonstrated a synergistic impact of UV scattering. Benefits from these insights include the ability to lower the molecular sunscreen's concentration and, thus, any potential negative effects, as well as the expenses associated with creating pricey sunscreens. Furthermore, it may be possible to create sunscreen solutions with lower and medium UV protection levels by using lipid nanoparticles. The miscibility of the active ingredient in the lipid used to produce the lipid nanoparticles is the primary determinant of their loading capacity. The German business Dr. Rimpler GmbH, located in Wedemark/Hannover, released the first two cosmetics utilizing nanostructured lipid carrier technology. The success of lipid nanoparticles in the antiaging sector was demonstrated in October 2005 when the products NanoRepair Q10 cream and NanoRepair Q10 serum (Dr. Kurt Richter Laboratorien GmbH, Berlin, Germany) were released onto the cosmetic market[88].

Table 2: Examples Of Marketed formulations of nanoparticles[89-91]

Product Name	Drug Name	Nanotechnology Platform	Indication
Doxil®	Doxorubin	Liposome(PEGylated)	Cancer (ovarian cancer)
Abraxane®	Paclitaxel	Nanoparticle Albumin-bound	Cancer (non-small cell lung cancer)
Feraheme®	Ferumoxytol	Iron oxide nanoparticles	Iron deficiency anaemia

Recent Research

Nanotechnology research has risen significantly over the last few decades, and the healthcare industry has also drawn more interest. Technological developments have enhanced our comprehension of some of the complex etiologists involved and increased the likelihood of early diagnosis and possible therapeutic uses of nanomedicine. Numerous Nano Systems have proven to be successful in reducing barriers in a number of healthcare fields, despite the fact that they have only been partially employed and integrated. Although the development of nanomedicines and nanodevices is still in its infancy, one tactic to hasten this process is to concentrate research efforts on developing innovative solutions to overcome the related challenges. The constant development of nanotechnology-based methods has sparked optimism that crippling and potentially fatal diseases may soon be effectively treated. Closing the gaps caused by inadequate efficacy and preclinical safety studies must be our top priority if we are to quickly and completely realize the vast potential of nanotechnology, which is now unrealized. While there are many problems that nanotechnology can solve, this does not mean that there are not any challenges or limitations. Recent developments in medication delivery using nanotechnology have completely changed how many diseases are treated, especially those related to infectious diseases, neurological diseases, and cancer. By enabling regulated release profiles, improved bioavailability, and targeted medication administration, nanotechnology reduces side effects and boosts therapeutic efficacy. Drug Delivery Systems Based on Nanoparticles: Nanoparticles can effectively transport medications to certain bodily locations due to their special physicochemical characteristics, such as a high surface area-to-volume ratio[92].The capacity of nanotechnology to target medications to particular cells or tissues is one of its primary benefits. This is frequently accomplished by

adding targeting ligands, including peptides, antibodies, or small molecules, to the surface of nanoparticles. These ligands bind selectively to receptors that are overexpressed on disease cells[93].

Conclusion

With notable advancements in targeting, bioavailability, and therapeutic results, nanotechnology is pushing the limits of medication delivery. The goal of current research is to overcome the obstacles of toxicity, scalability, and stability. Nanomedicines have the ability to treat a wide range of complicated illnesses as new technologies are developed, which bodes well for future treatments that are more individualized and efficient. By improving the functionality and efficiency of commonplace items, nanotechnology is simplifying our daily lives. By supplying cleaner, renewable energy and healthier air and water, it helps to maintain environmental purity for a longer-lasting future than would otherwise be possible. In direct response to the increasing interest in nanotechnology, top institutions, businesses, and organizations are increasing their investment in research and development. This area of science is at the forefront right now because of the substantial research being done to put nanotechnology into practice. It is now being evaluated for a number of innovative uses with the goal of improving the product or process's performance and efficiency, which would lower the cost and make it more affordable for a larger market. Nanotechnology has an exciting and promising future due to its effectiveness and minimal environmental impact. Nowadays, drugs are successfully delivered via nanoparticles. Nanoparticles, one of the most important tools in nanomedicine, offer significant benefits in drug transport and targeting, as well as the potential for combined therapy and diagnostics. Technically, the following tactics are difficult to implement: Technologies under investigation include viral-like systems for intracellular systems, biomimetic polymer architecture, systems that interact with my body smartly, nanochips for NPs release, carriers for advanced polymers for peptide/protein delivery, and control of sensitive drugs. Drug delivery systems were developed to control the quantity and pace of drug administration or to disperse pharmaceuticals. Most significant and well-established internal drug delivery research projects use formulations and dispersions that contain components as small as nanometers. This work built a nanoparticle data storage system after analyzing the earlier studies. By classifying them, going over the various ways to make them, and going over their numerous uses, this page provides an overview of nanoparticles. Our study's results indicate that throughout the previous several years, the prevalence of nanoparticles has rapidly increased. The costs of some of the produced nanoparticles are competitive, and there are several opportunities or potential projects that might be done. For example, the production of nanoparticles from plant materials has become more and more popular recently because it is both cost-effective and environmentally friendly[94].

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