STM JOURNALS

Research & Reviews: A Journal of
Pharmaceutical Science

ISSN: 2229-7006
Volume 16, Issue 2, 2025
May–August
DOI (Journal): 10.37591/RRJoPS

https://journals.stmjournals.com/rrjops

Review RRJoPS

A Review of Nanotechnology Application in Pharmaceutical and Health Care

Krutika Arvind More[1,*], Sulbha Gopal Patil[2], Sunil Pandit Pawar[3], Umakant Sanjay Jagtap[1], Aachal Vinod Jain[1]

Abstract

Nano drugs and nano delivery systems are a new but rapidly developing field where accoutrements in the nanoscale range are employed to serve as means of individual tools or to deliver remedial agents to specific targeted spots in a controlled manner. Nanotechnology provides numerous advantages in treating chronic diseases by enabling precise, site-specific, and targeted drug delivery. Recently, there have been several remarkable applications of nanomedicine, including chemotherapeutic agents, natural agents, immunotherapeutic agents, and more, in the treatment of various conditions. This review presents an updated overview of the recent advancements in nanodrugs and nanomedicine delivery systems, offering a comprehensive analysis of the discovery and utilization of nanomaterials to enhance the efficacy of both new and existing medicines (such as natural products), as well as enabling selective diagnosis through disease marker molecules. The opportunities and challenges of nanomedicines in drug delivery – ranging from synthetic and natural sources to clinical applications – are also discussed. Furthermore, this review includes insights into the emerging trends and future perspectives in the field of nanomedicine.

Keywords: Curricular unit, nanomedicines, nanoscience, druggist, pharmacy education

INTRODUCTION

Nanotechnology is distinctive in that it encompasses a wide range of academic fields, from abecedarian material wisdom to operations in particular care. The idea and capability of manipulating motes and supramolecular structures to produce bias with preprogrammed functions is pivotal to nanotechnology's part in medicine delivery. Now, appertained to as "nano-vehicles," conventional liposomes, polymeric micelles, and nanoparticles are only technically true in terms of scale. The present-day state of those traditional medicine delivery technologies would have developed regardless of the current nanotechnology revolution. To better understand the significance of nanotechnology in drug delivery, it could be useful to categorize medicine delivery methods by two distinct periods: before and after the nanotechnology revolution. This approach helps clarify the true impact of nanotechnology on how medications are administered and their effectiveness.

***Author for Correspondence**
Krutika Arvind More
E-mail: krutikamore490@gmail.com

[1]Student, B. Pharm, Department of Pharmaceutics, P. S. G. V. P. Mandal's College of Pharmacy, Shahada, Maharashtra, India
[2]Associate Professor, Department of Pharmaceutical Chemistry, P. S. G. V. P. Mandal's College of Pharmacy, Shahada, Maharashtra, India
[3]Principal, Department of Pharmacy, P. S. G. V. P. Mandal's College of Pharmacy, Shahada, Maharashtra, India

Received Date: February 28, 2025
Accepted Date: April 10, 2025
Published Date: April 24, 2025

Citation: Krutika Arvind More, Sulbha Gopal Patil, Sunil Pandit Pawar, Umakant Sanjay Jagtap, Aachal Vinod Jain. A Review of Nanotechnology Application in Pharmaceutical and Health Care. Research & Reviews: A Journal of Pharmaceutical Science. 2025; 16(2): 7–17p.

May negotiate to produce nano/ micro medicine delivery systems, considering the product of nano/ micro patches (or capsules). The maturity of contemporary nano/micro flyspeck medication technologies relies on double conflation. The main issues with present technologies are their low medicine-laden capacity, inefficiency, and inability to manage the size distribution. Using

nanotechnologies similar to nan patterning, it may be possible to manufacture nano/ micro patches with great loading effectiveness and largely homogenous flyspeck sizes [1].

Nanotechnology is a branch of applied science concerned with the design, fabrication, characterization, and operation of nanoscale accoutrements and technologies. This discipline of knowledge. category of technology in colloidal wisdom, biology, drugs, chemistry, and other scientific fields, and it entails the study of marvels and the manipulation of accoutrements on the nanoscale. Because of their size and structure, these accoutrements and systems constantly parade novel and drastically changing physical, chemical, and natural parcels. A key feature of nanotechnology is the "dramatically increased surface area to volume ratio" that it creates. This allows for more efficient interactions with other substances, enhancing the effectiveness of drug delivery and other applications [2].

Nanotechnology's size reduction is a fundamental process with numerous applications in pharmacy. It enhances drug solubility and bioavailability, reduces toxicity, improves release, and offers better delivery options. In most cases, size reduction is limited to the micron range, similar to pharmaceutical lozenge forms, such as greasepaint, confectionery, suspense, and so on. Medicines with nanoscale confines ameliorate performance in several lozenge formats. The primary benefits of nano-sizing include a smaller face area [3].

Pharmaceutical lore and Pharmacy:

- Lesser Solubility.
- Advanced dissolution rate.
- Increased oral bioavailability.
- Faster onset of the rape tic activity.
- Less amount of dose required.
- Lowered/ fasted variability.
- Decreased patient-to-patient variability.

Bottom-up inventions, the bottom-up and top-down technologies are the two abecedarian techniques for producing medication nano scale. Bottom-up processes begin with the molecules in result, and the molecules total to produce patches that might be liquid or amorphous. Bottom-up technologies come in a variety of forms. Method of precipitation.

Sono crystallization recrystallization of gas antisolvents GAS technologies from the top down technologies begin with huge chargers in the m range and progress to the nano dimension by shrinking the chargers. There are colorful types of top-down technology [4].

SIZE OF NANOTECHNOLOGY IN PHARMACY

Nanoparticles used in drugstore products can vary in size, generally ranging from 1 to 100 nanometers (nm) in diameter. The specific size of nanoparticles depends on their intended purpose and the expression system used in medicinal operations. Lower nanoparticles frequently have unique properties and are used for drug delivery systems, while larger bones.

May be employed for individual or imaging purposes. The precise size is precisely controlled to achieve the desired remedial or individual affairs. Nanoparticles used in drugstore products can vary extensively in size depending on their intended operations. Here are some examples of nanoparticles in drug stores with their typical size ranges. Liposomes are lipid-grounded nanoparticles used for medicine delivery. They generally range in size from 50 to 200 nanometers. Polymeric material made from biodegradable polymers; these nanoparticles typically range from 10 to 200 nanometers in size.

Gold nanoparticles are used in diagnostics and drug delivery; gold nanoparticles range from 1 to 100 nanometers in size. Iron oxide nanoparticles. These nanoparticles are used in imaging and medicine

delivery and generally range from 5 to 30 nanometers. Carbon nanotubes, although technically, nanotubes.

APPLICATION OF NANOTECHNOLOGY IN PHARMACY

Nanotechnology plays a significant role in biomedical and pharmaceutical products, as it facilitates everything from sundry diagnoses to drug delivery to human organs to target infectious diseases. Nanoparticles possess distinct biological properties useful for disease detection, prevention, treatment, drug delivery, and gene therapy, particularly for cancer and pulmonary diseases [5].

Due to having capability to bind, absorb, and carry small molecule drugs, DNA, RNA and prusins with high e efficiency Indeed, liposomal drug formulations lie, doxorubicin are widely used for the treatment of breast and ovarian cancers and Kaposi's sarcoma access fully Incorporation of liposomal drug formulations to and amylin cancer drags exhibited much better efficacy and safety as compared to conventional preparations [6].

Quantum dots are inorganic nanoparticles that consist of 10–50 atoms, and their diameter ranges from 2 to 10 nm. Because of their high-sensitivity and multicenter imaging properties, they have been used for the detection and diagnosis of cancer cells in in vivo conditions 158).

In addition to that, nanobiosensors can be employed for the detection of leading causes of cancer, such as environmental pollutants, pathogens, and carcinogenic gases 139, 60). Nanomaterials have been incorporated into a drug formulation, such as active constituents (nanocrystals), excipients (drug-metal complexes), drug carriers (liposomes), or as complexes/conjugates (drug protein) [7].

Nanotechnology may also have future nutritional health benefits. People with type one diabetes are expected to be able to consume a non-engineered biodegradable material containing insulin, which can be released as a response to high blood glucose concentrations 1611. That is the interest in the application of nanotechnology-derived anti-inflammatory agents in the mucosal lining of patients with inflammatory bowel disease or Crohn's disease.

It is also thought that the use of nematology on some nutrients can enable individuals to expand their limited food supply, specific medicine delivery, imaging, or individual requirements in the field of drug store and drug to relieve or choose.

There are various nanoparticle-based delivery systems that have been exploited for diagnostic and therapeutic applications (Table 1) [8].

METHODS TO DEVELOP NANO SYSTEMS

Metal Nano Particle

Metal nanoparticles (MNPs), including gold, silver, iron, platinum, ceramic, quantum dots, and superparamagnetic particles, are used due to their unique optical, magnetic, electrical properties, and small size. MNPs are produced through physical, chemical, and green methods. Physical methods, like evaporation, condensation, and laser ablation, result in less solvent contamination and uniform distribution. Chemical methods involve reducing agents, such as ascorbate, sodium borohydride, and Tollen's reagent. Biological methods use bacteria, fungi, and plant species for MNP production. Magnetic nanoparticles can be controlled with an external magnetic field, allowing them to simultaneously detect and treat diseases [9–22].

DRUG DELIVERY MECHANISM USING NANOPARTICLES

Nanoparticles (NPs) serve as "drug bullets" by attaching therapeutic drugs, allowing targeted delivery without altering the drug. Nanotechnology-based drug delivery systems (DDS) enable precise drug delivery to specific sites, especially for drugs that require special pH conditions, low solubility, or high concentrations for effectiveness. Drug attachment to polymers can be done through encapsulation, noncovalent complexation, or conjugation via a linker. The size of the polymer-drug conjugate is

critical, as it can be controlled by adjusting the polymer's molecular weight, influencing drug solubility, hydrophobicity, and permeability.

Table 1. Pros and cons of various nanostructure-based drug delivery carriers.

Drug Carrier	Advantages	Disadvantages
Metal Nanoparticles [23]	• Multimodal Applications • High Surface Area	• Metal Toxicity • Stability • Storage
Carbon Nanotubes [24]	• Water Soluble • Multifunctional	• Expensive to Produce • Low Degradability
Liposomes [25]	• Biodegradable • Load Hydrophobic and Hydrophilic Drugs	• Poor Drug Loading • Immunogenicity
Liquid Crystalline Particles [26[	• Thermally Stable • Biodegradable • Bioadhesion	• Complex and Difficult to Prepare • Low Encapsulation Rate
Dendritic Systems [27]	• Monodisperse Molecules with a High Control over the Critical Molecular Design Parameter	• Highly Expensive Synthesis Processes • Non-specific Toxicity
Polymers [28]	• Biocompatible • Biodegradable (Depending on Polymer Nature) • Easy to Modify • Controlled Drug Release	• Low Cell Affinity • Toxicity of Degradation Products
Hydrogels [29]	• High Water Content and Biocompatibility • Could be Gelling at Body Temperature	• Trend to be Fragile • Expensive, Especially the Smart Hydrogels • Behavior Difficult to Predict
Cyclodextrins [30]	• Hight Aqueous Solubility • Chemical Stability	• Could be Irritant
Aptamers [31]	• Good Chemical Stability • Isotropic Properties • Unlimited Shelf Life • Highest Specificity and Affinity to the Target	• Unpredictable Risk • Complex and Costly Procedures

The drug loading capacity depends on the matrix density, and it can be increased by reducing solubility, enhancing ionic interactions, or maximizing drug absorption. Drugs can be covalently attached to polymers via pH- or enzyme-sensitive linkers. To avoid immune recognition and destruction, the NP surface is often decorated with biodegradable, hydrophilic copolymers, such as polyglycolic acid (PGA) or poly-lactic acid (PLA), which control the degradation rate and drug release.

PEG-based copolymers are commonly used for their ability to condense nucleic acids into nano-sized particles with protective properties. Inside the cell, NPs are internalized into endosomes, which merge to form larger structures, releasing the drug in response to enzymes or acidic conditions. Drug release can be controlled by altering the polymer's degradation rate, pore size, or NP size, with smaller NPs having larger surface areas that enhance drug release [10, 11].

Genetic Engineering Method

It can control the structural, functional properties of recombinant protein-based drug carriers, such as elastomer-like proteins and silk-like proteins. GEM can control molecular weight, hydrophobicity, drug conjugate site, and secondary structure, as well as provide higher transfection efficiency [12].

Electro Sprayed Technique

The NP produces a setup consisting of a syringe pump with polymer solution connected to high-voltage power supply. A metal foil collector is placed opposite a ground electrode. Flow rate and applied voltage depend on the type of solution used in the process. Solid particles can be produced by solvent

evaporation. Electro-sprayed particles can be used to deliver drugs directly without polymer to the target site [10].

Nano Crystal

Drugs that require injection into cells are produced on a nanoscale, enabling them to function as their own carriers. Drug particles are readily water soluble because of intensive. The drug particle is reduced to a tetanizing range and stabilized surface by polymeric macromolecules and nonionic surfactants. The size decreases mean increased surface area of the drug. Ultimately, solubility dissociation is increased, and plasma concentration rises. Nanocrystals help reduce carrier particle accumulation, allowing direct drug incorporation at the target site. They remain stable in aqueous dispersion without stabilizers and are efficiently taken up by tumor cells. Polymeric nanoparticles (10–100 nm) include synthetic polymers like polyglycolic acid, polyacrylamide, and natural polymers like albumin, gelatin, chitosan, and DNA. These nanoparticles can be biodegradable or non-biodegradable and are produced using methods like solvent diffusion, emulsification, and supercritical carbon dioxide. Recently, smart polymers have been developed that respond to environmental signals, such as temperature, electrical, mechanical strength, and enzymes. Various mechanisms are used to incorporate drugs into these nanoparticles.

- Covalent bonding between the drug and the polymer carrier.
- Hydrophobic interactions between the drug and the carrier.
- Water-filled depot for hydrophilic drug incorporation.

The drug is released into the target site by diffusion, desorption, and erosion. Polymeric NPs deliver drugs to the target site with minimal toxicity and undergo hydrolysis in the body, producing biodegradable metabolites like lactic acid (Figure 1) [13].

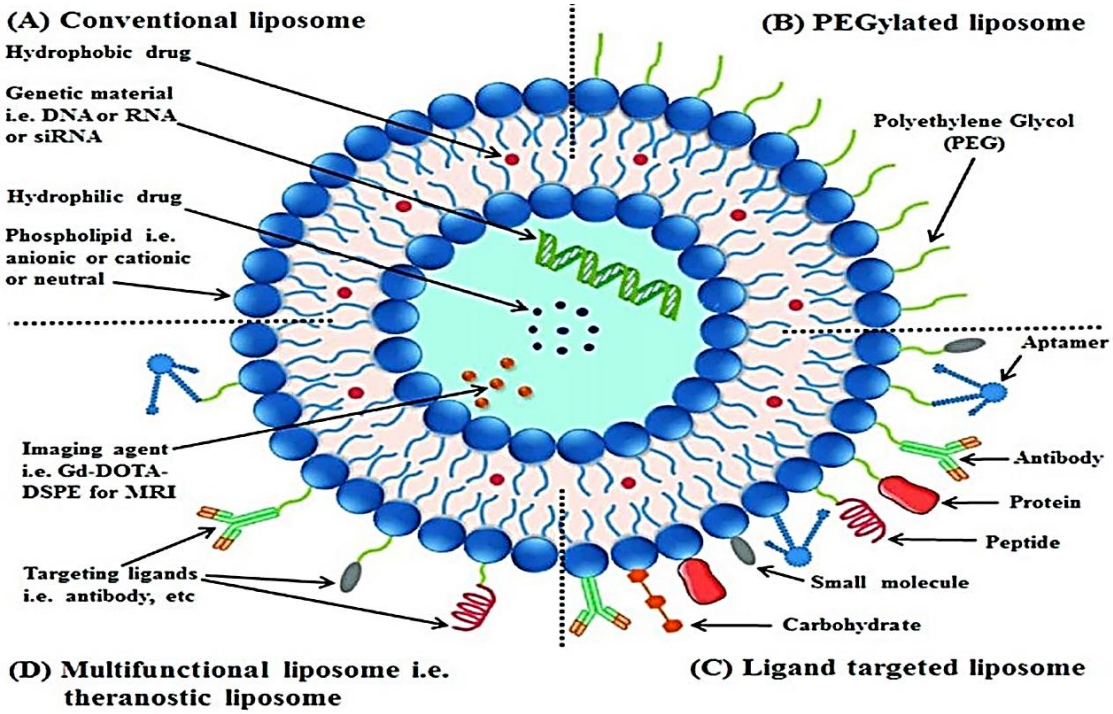

Figure 1. Liposomes.

TYPES OF PHARMACEUTICAL NANO SYSTEMS

- The first nanomaterials used in drug delivery were lipid vesicles, known as liposomes, described in 1976. Liposomes are spherical vesicles made of amphiphilic phospholipids and cholesterol, which form bilayers to encapsulate an aqueous core. The phospholipids arrange themselves in a bilayer to

shield their hydrophobic tails from water, while their hydrophilic head groups remain in contact with the aqueous phase. Liposomes can encapsulate hydrophobic drugs within their membrane and hydrophilic substances in their core [14].

- Dendrimers, with their unique molecular structure, can carry various drugs through covalent conjugation or electrostatic adsorption. Typically ranging from 10 to 100 nm, dendrimers have multiple functional groups on their surface, making them ideal carriers for targeted drug delivery. They are similar in size to many proteins and biomolecules like insulin, cytochrome C, and hemoglobin. Second-generation dendrimers have a size like DNA (2.4 nm), while fifth and sixth-generation PAMAM dendrimers resemble cellular lipid membranes (5.5 nm). A simple and quick method for forming these involves adding an organic solution containing a polymer and a lipophilic drug into an aqueous solution dropwise under constant stirring. These polymer patches are highly flexible and have both hydrophilic and hydrophobic properties [15].
- *Carbon Nanotubes:* Carbon nanotubes (CNTs) are cylindrical structures made of benzene rings and have been used in biology for various applications. They serve as sensors for detecting DNA and proteins, diagnostic tools for distinguishing different proteins from serum samples, and carriers for delivering drugs, vaccines, or proteins. Single-walled carbon nanotubes (SWCNTs) are used as platforms for studying protein-protein interactions and developing highly specific electronic biomolecule sensors. Carbon nanotubes consist of hexagonal carbon networks, with diameters around 1 nm and lengths ranging from 1 to 100 nm. There are two types of nanotubes: single-walled (SWCNTs) and multi-walled nanotubes (MWCNTs). These small molecules possess unique size, shape, and exceptional physical properties [16].
- *Quantum Dots (QDs):* Quantum dots (QDs) are used to track individual glycine receptors (GlyRs) and study their dynamics in living cell membranes, ranging from milliseconds to seconds. Recently, semiconductor quantum dots have gained attention due to their importance in microelectronics, optoelectronics, and cellular imaging. Quantum dots are semiconductor materials with a core covered by a protective shell. a shell to ameliorate optic parcels. Their parcels appear from their physical size, which ranges from 10–100A0 in compass (The Nanotech Revolution in Drug Delivery 2007). Polymers for preparing nanoparticles include poly (alkyl cyanocrystalates), poly (mythologeme Manolete 2.1.2), polyesters, e.g., poly (lactic acid), poly (ε-caprolactone), and their copolymers. For the Nano sphere medication, natural macromolecules, similar to proteins and polysaccharides, non-polar lipids, and metal oxides and silica, can also be used. Some important marketable products are Onco TCS, Aero LEF, Basulin, Hepialid, Trans medicine, Xyotax, etc. [17].
- *Polymeric Micelles:* Polymeric micelles are nanoparticles with a hydrophilic outer shell and a hydrophobic inner core. They are mainly of two types: hydrophobically assembled micelles and polyion-complex micelles. The former consists of amphiphilic copolymers with hydrophobic and hydrophilic blocks, where the balance between these blocks in water leads to the formation of nano-sized particles. Poly (ethylene glycol) (PEG) is often used as the hydrophilic block in many block copolymers.
- The properties of the micelles depend on the nature of the hydrophobic core-forming materials, such as biodegradable polyesters like poly(lactic acid) (PLA), poly(caprolactone) (PCL), and poly (glycolic acid). These micelles are generally smaller than 100 nm in size, and their hydrophilic surface helps protect them from nonspecific uptake by the reticuloendothelial system. Micelles in solution form aggregates with a spherical structure, where the hydrophobic core is shielded from water by a hydrophilic outer layer. These micelles are used for delivering poorly water-soluble drugs. Commercial formulations include CrEL-paclitaxel and phenylboronic acid-loaded polymeric micelles [18].
- Various nanoparticles, including silver and gold, are significant for biomedical applications. A range of ligands, such as sugars, peptides, proteins, and DNA, have been attached to nanoparticles. These are used for active drug delivery, bioactive discovery, bioassays, imaging, and other applications due to their surface functionalization capabilities. Commercially available products include CdSe QDs, along with silver and gold nanoparticles [19].

Fullers

A Fullerene is any patch in the form of a concave sphere, ellipsoid, or tubular structure composed entirely of carbon. They're generally named after Buckminster Fuller, who designed geodesic physical structures and buildings based on this geometry. A Buckyball, a carbon-grounded hollow geometric sphere, was first set up in soot developed from a laboratory trial. The molecular frame is entirely composed of an expansive p-conjugated carbon shell. They are typically synthesized by poorly understood empirical methods; for instance, the vaporization of graphite by resistive heating yields grunge from which fullerenes can be insulated chromatographically fullerenes can veritably efficiently bind and inactivate revolutionaries that play a pivotal part in the development of conditions of the central nervous system (e.g., Parkinson, Alzheimer) and cardiovascular conditions (C60 and C70 (99 chastity)) (MER Corp. (Tucson, AZ)), C76, C78, and C84, etc., are the suitable exemplifications of fullerenes [20].

Research and Development of Nanotechnology

Assiduity to shield off the generics' assiduity from their hard-earned gains. Also, medicines with these new capabilities will probably find operations in new requests. Simplest in this order are polymer-reprised medicines, similar to MultiSal™, DermaSal™, and MatrixSal™ from the company Salvona. Similar polymer-reprised medicines can be fine [21, 22].

Deliver the medicines using several stimulants, such as pH, temperature, and water. In addition to simple polymer encapsulation, more sophisticated nanotechnology tools, similar to nano core-shell designs, are also being developed to further fine-tune delivery and release. For illustration, in a recent work, Sengupta et al. demonstrated a new approach for treating angiogenesis using a core-shell armature wherein the polymer core has a cytotoxic agent with the encapsulation of the anti-angiogenesis agent in the girding phospholipid block, similar to a design that enables temporal targeting of the excrescence vasculature [23].

Nanotechnological pharmaceutical: Drug delivery system pharmaceutical industry now uses nanotechnology as a platform for new technology development. It's the wisdom that deals with the processes that occur at the molecular level and on the nano length scale size. It opened new opportunities for enhancement in different aspects of pharmaceutical manufacturing, e.g., medicine design. Nanotechnology in medicine is vast, ranging from smart materials for tissue engineering to intelligent drug delivery tools. Novel drug delivery systems, a key aspect of nanotechnology, focus on manipulating molecules and supramolecules to create devices with programmed functions. Examples of current nanomedicine delivery systems include liposomes, polymeric micelles, nanoparticles, and dendrimers [23].

Liposomes are small, artificial vesicles made from cholesterol and non-toxic phospholipids. They are highly advanced for targeted drug delivery due to their size and amphiphilic (hydrophobic-hydrophilic) properties. Polymeric nanoparticles are colloidal carriers known for their biocompatibility, non-immunogenicity, non-toxicity, and biodegradability, making them ideal for targeted and intracellular delivery [24–26].

Evaluation of nanoparticles involves tailored protocols or experimental models to assess targeting efficacy and associated risks, including distribution, interaction, hematology, serum chemistry, and histopathology. Figure 2 illustrates the complexity of these models. Biodistribution studies track how nanoparticles accumulate in tissues or organs, with radiolabels used to trace nanoparticles in living or deceased subjects. The rate of nanoparticle excretion and metabolism at different time points post-exposure is measured. Additionally, changes in serum chemistry and cell types after exposure help determine in vivo toxicity. The cytotoxicity position convinced by a nanoparticle is determined by the histopathology of the cell, tissue, or organ following exposure. Below, the conventional styles of assessing the cytotoxicity of the nanoparticles, such as proliferation tests, apoptosis assays, necrosis assays, oxidative stress assays, and DNA damage assays, are described briefly.

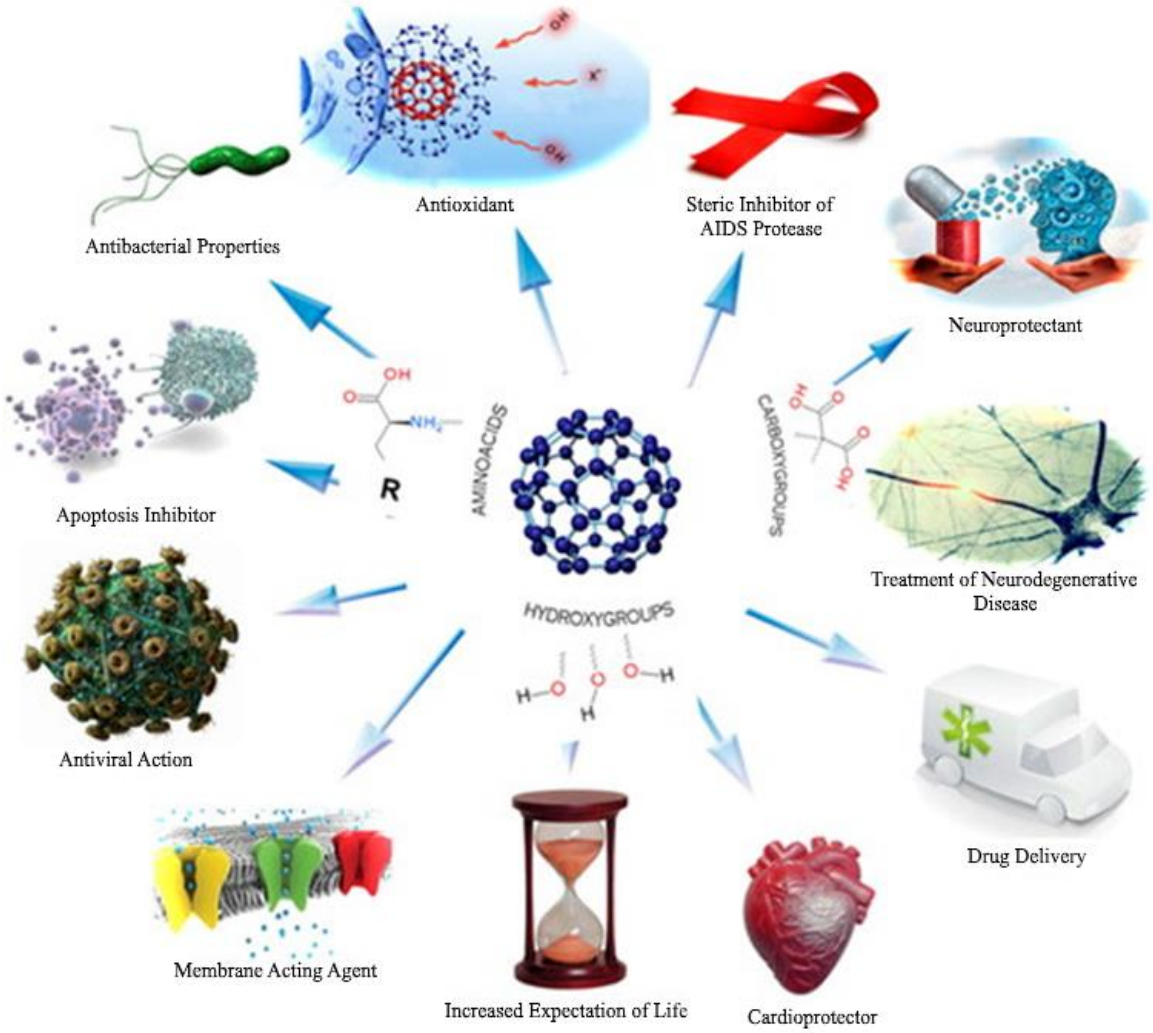

Figure 2. Research and development of nanotechnology in various aspects.

EXPERIMENTAL MODEL FOR EVALUATING NANOPARTICLE

Tailored protocols or experimental models to assess targeting efficacy and associated risks include distribution, interaction, hematology, serum chemistry, and histopathology. Figure 2 highlights the complexity of these models. Biodistribution studies examine how nanoparticles accumulate in tissues or organs, with radio labels used to trace them in living or deceased animals. Measuring nanoparticle excretion and metabolism at various time points after exposure helps determine their interaction.

Proliferation assays are used to assess metabolically active cells and characterize cellular metabolism upon NP exposure. The most frequently employed tetrazolium swab for the in vitro toxin assessment of nanoparticles is 3-(4,5-Dimethyl-thiazol-2-yl)-2,5-diphenyltetrazolium platitude (MTT). The procedure is profitable since it produces quick results, can be performed in a multiplex format, and requires minimal revision of the model cells. The assay detects tetrazolium salts, indicated by changes in culture media, pH, ascorbate, and cholesterol levels. Since the MTT test generates formazan, color-producing assays, like XTT or WST-1, are preferred.

Membrane integrity assays assess cell viability and necrosis caused by nanomaterials. Trypan Blue staining can identify dead cells, as it enters only non-viable cells. Cell membrane stability is evaluated through Trypan Blue exclusion. Another method measures cell leakage, while electron microscopy allows observation of membrane damage and material leakage [27–29].

NANOTECHNOLOGY USED FOR VARIOUS DISEASES

Nanoparticles Are Used for Tuberculosis Treatment via Chemotherapy

The enhanced effectiveness of anti-TB drugs encapsulated in nanoparticles can be attributed to their altered release patterns after oral administration. Rifampin, isoniazid, and pyrazinamide, core anti-TB drugs, were co-loaded in PLG-based nanoparticles. These nanoparticles maintained therapeutic drug levels in tissues for up to 10 days, while free drugs remained in plasma for just 1 day after injection.

Topical Drug Delivery for Skin Disorders

Nanoparticles, electrospun fiber mats, with their high surface area-to-volume ratio, facilitate efficient dispersion of both hydrophobic and hydrophilic drugs, making them excellent for topical drug application. Additionally, liposomes, solid lipid nanoparticles (SLNs), and nanostructured lipid carriers are also gaining attention for their potential in topical drug delivery.

Application of Nanoparticles for Alzheimer's Disease

Nanoparticle-mediated drug delivery is a promising approach for enhancing CNS penetration in the treatment of neurodegenerative diseases like Alzheimer's. PNPs are particularly effective because they can open blood-brain barrier tight junctions, extend drug release, and protect drugs from enzymatic breakdown. Nanoparticles also deliver anticancer agents in nano-oncology, improving cancer cell targeting and overcoming multidrug resistance in tumors.

Nanoparticles Used Against COVID-19

Since 2020, scientists have focused on developing treatments to combat the global COVID-19 pandemic. In 2021, nanoparticle technology's importance in creating therapeutic formulations for diagnosis, treatment, and long-term immunity against COVID-19 was highlighted. The rapid development of COVID-19 nanoparticle-based vaccines (CNPBV) was facilitated by the recorded genome structure of coronaviruses and prior knowledge of the spike protein sequence. The spike proteins on the virus surface, with strong affinity for nanoparticles and host cell receptors, were key in developing these formulations.

RESULTS AND DISCUSSION

Several nanotechnology projects have been commercialized, but many still require full life cycle assessments. The number of nanotechnology innovations continues to grow; however, research on their potential environmental and biological impacts remains limited. As the world rapidly adopts this technology, more focus should be placed on understanding its possible effects to ensure that nanomaterials do not become the next major hazard of the 21st century. The long-term sustainability of this technology may depend on identifying and mitigating its risks.

Nanotechnology, an emerging field developing at an exponential rate, exploits the unique properties of materials at the nanoscale. Although still in its early stages, it shows promise in many areas, such as medicine, computer technology, food industries, construction, and environmental protection. The many exciting products it promises have drawn significant attention. However, despite the rapid implementation of nanotechnology in commercial products, there is insufficient toxicological data on the environmental and biological impacts of these nanomaterials. As nanotechnology gains broader application across various sectors, it is crucial to understand its potential effects for its long-term sustainability. It is equally important to establish proper regulations and standards to govern the research and commercial use of this emerging technology.

CONCLUSIONS

Pharmaceutical nanotechnology has emerged as a dynamic field with significant potential in diagnosis and treatment. It has become a key area of interest, offering new opportunities as a carrier for potent medicines and diagnostics. Well-established as a technology for drug delivery, diagnostics, and treatment, pharmaceutical nanotechnology uses nano-engineered tools to improve healthcare outcomes. It allows for advancements in materials, medical devices, and the development of new technologies while overcoming the limitations of traditional methods.

Nanotechnology is driving a healthcare revolution, focusing on preventative population health management. It addresses challenges in targeted treatment delivery, reduces the risk of side effects, and enhances therapeutic effectiveness.

This technology is ideal for the detection, treatment, and gene therapy of cancer. Nanomedicine is one of the most promising applications of nanorobotics. Its uses span various fields, including vaccine development, drug delivery, wearable devices, personal and imaging equipment, and antimicrobial products. The advancement of more effective drugs, improved devices, and early detection of various diseases is expected to lead to the rise of nanomedicines.

By combining traditional anti-cancer drugs with nanoscale technologies, drugs can be effectively delivered and distributed within the brain. This technology holds vast potential and benefits across many areas of medicine. Nanomedicines are produced by a specific combination of manganese and citrate using nanotechnology methods. It is possible to develop tailored mechanisms for drug delivery, new personal treatment approaches, and nanoscale medical devices.

REFERENCES

1. Pandey R, Khuller GK. Nanotechnology based drug delivery system(s) for the management of tuberculosis. Indian J Exp Biol. 2006;44:357–366.
2. Jain NK. Pharmaceutical Nanotechnology. Sagar: Dr. Hari Singh Gour University; 2007.
3. Mansoori GA, Bastami TR, Ahmadpour A, Eshaghi Z. Environmental application of nanotechnology. Annu Rev Nano Res. 2008:439–493.
4. Liu P. Nano-crystal formulation for poorly soluble drugs. Helsinki: Helsinki University Printing House; 2013.
5. D'Mello S, Cruz C, Chen ML, et al. The evolving landscape of drug products containing nanomaterials in the United States. Nat Nanotechnol. 2017;12:523–529.
6. Nguyen VP, Le Trung H, Nguyen TH, Hoang D, Tran TH. Synthesis of biogenic silver nanoparticles with eco-friendly processes using Ganoderma lucidum extract and evaluation of their theranostic applications. J Nanomater. 2021;2021(1):6135920.
7. Di Paolo A. Liposomal anticancer therapy: pharmacokinetic and clinical aspects. J Chemother. 2004;16(Suppl 4):90–93.
8. Tyner KM, Zheng N, Choi S, et al. How has CDER prepared for the nano revolution? A review of risk assessment, regulatory research, and guidance activities. AAPS J. 2017;19:1071–1083.
9. Meng E, Hoang T. Micro- and nano-fabricated implantable drug-delivery systems. Ther Deliv. 2012;3(12):1457–1467.
10. Sridhar R, Ramakrishna S. Electrosprayed nanoparticles for drug delivery and pharmaceutical applications. Biomatter. 2013;3(3):e24281.
11. Stevenson CL, Santini JT Jr, Langer R. Reservoir-based drug delivery systems utilizing microtechnology. Adv Drug Deliv Rev. 2012;64(14):1590–1602.
12. Zhang Y, Chan HF, Leong KW. Advanced materials and processing for drug delivery: the past and the future. Adv Drug Deliv Rev. 2013;65(1):104–120.
13. Wilczewska AZ, Niemirowicz K, Markiewicz KH, Car H. Nanoparticles as drug delivery systems. Pharmacol Rep. 2012;64(5):1020–1037.
14. Bawarski WE. Nanomedicine. Nanotechnol Biol Med. 2008;4:273–282.
15. Zhang L, Gu FX, Chan JM, Wang AZ, Langer RS, Farokhzad OC. Nanoparticles in medicine: Therapeutic applications and developments. Clin Pharmacol Ther. 2008;83(5):761–769.
16. Jain KK. The role of nanobiotechnology in drug discovery. Drug Discov Today. 2005;10(21):1435–1442.
17. Khuspe P, et al. A comprehensive review on novel pharmaceutical nanotechnology and its applications. Indo Am J Pharm Sci. 2017;4(12).
18. Rangasamy M. Nano technology: A review. J Appl Pharm Sci. 2011;1(2):8–16.
19. Kumar CSSR. Nanomaterials for medical diagnosis and therapy. Weinheim: Wiley-VCH; 2007.
20. Techconnect.org. (2024). Nanotechnology 2008: Life Sciences, Medicine & Bio Materials –

Technical Proceedings of the 2008 NSTI Nanotechnology Conference and Trade Show, Volume 2 – TechConnect Briefs [Online]. Techconnect.org. Available from: https://briefs.techconnect.org/books/nanotechnology-2008-life-sciences-medicine-bio-materials-technical-proceedings-of-the-2008-nsti-nanotechnology-conference-and-trade-show-volume-2/.

21. Stern E, Klemic JF, Routenberg DA, et al. Label-free immunodetection with CMOS-compatible semiconducting nanowires. Nature. 2007;445(7127):519–522.
22. Amiji M. Nanotechnology for drug delivery: An overview. Boston: Northeastern; 2006.
23. Bhatia S. Nanotechnology and its drug delivery applications. 2016.
24. Marshall NJ, Goodwin CJ, Holt SJ. A critical assessment of the use of microculture tetrazolium assays to measure cell growth and function. Growth Regul. 1995;5:69–84.
25. Hussain SM, Frazier JM. Cellular toxicity of hydrazine in primary rat hepatocytes. Toxicol Sci. 2002;69:424–432.
26. Gelperina S, Kisich K, Iseman MD, Heifets L. The potential advantages of nanoparticle drug delivery systems in chemotherapy of tuberculosis. Am J Respir Crit Care Med. 2005;172(12):1487–1490.
27. Goyal R, Macri LK, Kaplan HM, Kohn J. Nanoparticles and nanofibers for topical drug delivery. J Control Release. 2016;240:77–92.
28. Hashemi Goradel N, Ghiyami-Hour F, Jahangiri S, et al. Nanoparticles as new tools for inhibition of cancer angiogenesis. J Cell Physiol. 2018;233(4):2902–2910.
29. Bobo D, Robinson KJ, Islam J, Thurecht KJ, Corrie SR. Nanoparticle-based medicines: A review of FDA-approved materials and clinical trials to date. Pharm Res. 2016;33(10):2373–2387.

