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Review Article

Revolutionizing Herbal Therapeutics: Exploring Advanced Nanotechnology Drug Delivery System (NDDS)

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ABSTRACT

Nanotechnology has revolutionized various fields, including drug delivery systems. In recent years, there has been a growing interest in utilizing nanotechnology to enhance the efficacy and delivery of herbal drugs. This review explores the applications of nanotechnology in herbal drug technology, focusing on the strategies employed to improve solubility, bioavailability, stability, and targeted delivery of herbal bioactives. Various nanoformulations such as nanoparticles, liposomes, micelles, and nanoemulsions have been developed to overcome the limitations associated with traditional herbal formulations. Moreover, the synergistic effects of combining nanotechnology with herbal medicine have shown promising results in treating various diseases, including cancer, diabetes, and inflammatory disorders. Additionally, this review discusses the challenges and future perspectives in the application of nanotechnology in herbal drug technology, highlighting the importance of interdisciplinary research collaboration to harness the full potential of this innovative approach for improved healthcare outcomes.

INTRODUCTION

Since immemorial times, herbal drugs, remedies and natural extracts have been in use for treating various diseases. Ayurveda is one of the oldest medical science practiced in India. Herbal medicine has thousands of constituents which works simultanously againt many diseases and has very few side effects as compared to allopathic system. The drugs has gain high importance because it has more advantages than others medical disciplines. For a long time, herbal medicine were not cobsidered for development of noval formulations due to lack of scientific justification and processing difficulties. However, most of the herbal drugs are insoluble in biological fluids leads to low bioavailability, insolubility,

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increased excretion rate and the need for repeated administration and have limited their therapeutic potential. This results in poor patient compliance.

The introduction of novel drug delivery systems (NDDSs), particularly leveraging nanotechnology, addresses these limitations effectively. This intersection of nanotechnology and herbal medicine holds promise for enhancing drug efficacy, reducing toxicity, and improving patient compliance. NDDS combines various methods of pharmaceutics for drug formulation, biochemistry, molecular biology, process and technology. Nanotechnology is type of novel drug delivery system which aims to formulate nanoparticles of size 1-100nm containing active drug in it. The nanocarriers are made of safe materials including lipids, synthetic and natural polymers, polysaccharides, etc. The application of nanotechnology in herbal drug delivery systems marks a significant advancement in pharmaceutical research, revolutionizing the traditional approach to utilizing medicinal plants. Integration of the nanocarriers as a novel drug delivery system in the herbal medicine is essential to Conflict more chronic diseases like asthma, diabetes, cancer, and others.

HISTORY AND DEVELOPMENT

The history and development of the application of nanotechnology in herbal drug delivery systems represent a fascinating journey at the intersection of traditional medicine and cutting-edge technology.

1. **Early Explorations (2000s):**

The initial forays into applying nanotechnology to herbal medicine occurred in the early 2000s. Researchers began recognizing the challenges associated with traditional herbal formulations, such as poor bioavailability and solubility issues. Nanotechnology, with its ability to manipulate materials at the atomic and molecular levels, offered a promising solution to enhance the therapeutic efficacy of herbal remedies.

2. **Nanoparticles and Beyond (Mid-2000s to 2010s):**

During this period, significant strides were made in developing various nanocarriers for herbal constituents. Polymeric nanoparticles, liposomes, solid lipid nanoparticles (SLNs), and nanoemulsions emerged as key players in the realm of novel drug delivery systems. These nanocarriers not only addressed issues of solubility but also provided controlled and sustained release, improving the overall effectiveness of herbal formulations.

3. **Advancements in Formulation Techniques (2010s to Present):**

The last decade has witnessed a refinement of nanotechnology-based formulation techniques for herbal drugs. Researchers have focused on optimizing the size, composition, and surface properties of nanoparticles to achieve specific therapeutic goals. Techniques such as nanosizing, coacervation, and emulsification have been employed to tailor nanocarriers for diverse herbal extracts.

4. **Safety and Biocompatibility (Ongoing):**

Ensuring the safety and biocompatibility of nanocarriers remains a crucial aspect of development. Researchers have explored the use of biodegradable polymers, lipids, and polysaccharides to construct nanocarriers that are not only effective in drug delivery but also safe for therapeutic use.

5. **Clinical Trials and Commercialization (Current Landscape):**

The application of nanotechnology in herbal drug delivery has progressed to the stage of clinical trials for certain formulations. As promising results emerge, pharmaceutical companies are showing increasing interest in the commercialization of these nanotechnology-based herbal products. The ongoing development in this field represents a harmonious blend of ancient herbal wisdom and modern technological innovation, paving the way for a new era in herbal medicine with enhanced efficacy and targeted delivery.

NECESSACITY OF NDDS IN HERBAL MEDICINE

The efficacy of herbal drugs is significantly affected by acidic pH of the stomach and liver metabolism. The application of nanocarriers in herbal remedies proves crucial as they enable the optimal amount of the drug to reach the intended site of action. Nanocarriers, with their small size, bypass barriers like stomach acidity and liver metabolism, ensuring prolonged circulation in the bloodstream. This not only enhances the therapeutic effect but also addresses the issue of achieving the minimum effective level required for the desired outcome. The incorporation of nanotechnology in herbal drugs addresses several critical needs, enhancing their overall effectiveness and therapeutic potential.

1. Improved Bioavailability:

Nanotechnology allows for the creation of nanocarriers that enhance the solubility of poorly water-soluble herbal constituents. This, in turn, improves the bioavailability of active components, ensuring a higher proportion of the administered dose reaches the bloodstream.

2. Targeted Drug Delivery:

Nanocarriers enable precise targeting of herbal drugs to specific cells or tissues, optimizing therapeutic outcomes. This targeted delivery minimizes off-target effects and ensures that the active constituents reach the intended site of action in a controlled manner.

3. Protection of Active Ingredients:

Herbal drugs often contain sensitive compounds that may degrade or lose efficacy during digestion or processing. Nanocarriers act as protective shields, preserving the stability of these active ingredients and preventing their degradation in the harsh conditions of the digestive system.

4. Controlled Release and Prolonged Action:

Nanotechnology facilitates the design of controlled-release systems, allowing for a sustained and prolonged release of herbal compounds. This not only improves patient compliance by reducing the frequency of administration but also ensures a more consistent therapeutic effect over time.

5. Overcoming Insolubility Challenges:

Many herbal compounds suffer from poor solubility, limiting their absorption and effectiveness. Nanocarriers, such as nanoparticles and liposomes, overcome these solubility challenges, enhancing the overall utility of herbal drugs.

6. Reduced Side Effects:

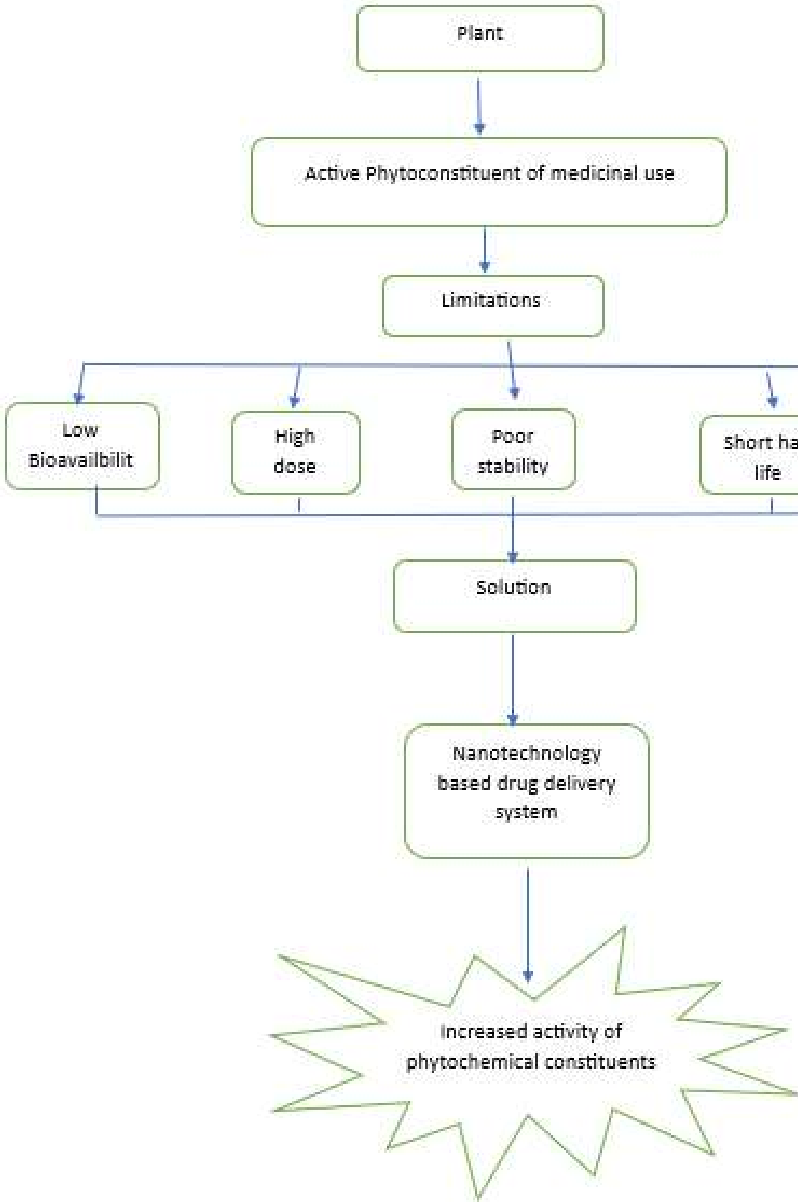
Nanotechnology can minimize systemic exposure and reduce the potential for side effects by precisely delivering herbal constituents to the target site. This is particularly important for herbal medicines with complex compositions where unwanted effects on non-target tissues may occur.

7. Modernization of Herbal Medicine:

Incorporating nanotechnology modernizes traditional herbal medicine, bridging the gap between ancient knowledge and contemporary pharmaceutical advancements. This infusion of technology adds precision and efficiency to herbal formulations, making them more aligned with modern healthcare standards.

8. Commercial Viability:

The application of nanotechnology increases the commercial viability of herbal drugs by addressing formulation challenges and improving therapeutic outcomes. This attracts investment and supports the development of advanced herbal pharmaceuticals.



NANOTECHNOLOGY IN NDDS

The nanotechnology system consists of nanoparticles of size 1-100nm Nanomaterials are a central component of nanotechnology systems. These materials may include nanoparticles, nanotubes, nanocomposites, and other structures designed and engineered at the nanoscale. Nanoparticles are converted to nanodevices which gives various advantages including the route of administration and increased therapeutic effects, which makes this nanotechnology more developed and widely studied by researchers. Herbal medicines using nanotechnology-based delivery systems have great potential and unique properties, such as being able to convert less soluble, poorly absorbed, unstable substances into promising drugs. Therefore, nanotechnology-based delivery systems represent a promising prospect for enhancing herbal activity and overcoming the dilemmas associated with herbal medicine

ADVANTAGES

1. Improved Bioavailability

2. Nanocarriers allow for precise targeting of herbal drugs to specific cells or tissues, minimizing off-target effects
3. Protection of Sensitive Constituents
4. Overcoming Solubility Challenges
5. Nanotechnology facilitates the design of controlled-release systems for herbal drugs.
6. Nanocarriers contribute to minimizing systemic exposure of herbal drugs, reducing the potential for side effects.

DISADVANTAGES

1. The safety of nanomaterials used in drug delivery systems is a significant concern
2. The use of nanocarriers may pose biocompatibility challenges, leading to immune responses or adverse reactions
3. Limited Understanding of Nanotoxicology
4. The production of nanotechnology-based herbal formulations may incur higher costs due to the complexity of manufacturing processes and the use of specialized technologies.

APPLICATIONS OF NANOTIZED HERBAL DRUGS IN SOME CONDITIONS / DISEASES

1. **Cancer Treatment:**

Example: Curcumin-loaded nanoparticles in the treatment of breast cancer.

Rationale: Curcumin, a compound from turmeric, has anti-cancer properties, but its poor solubility limits its effectiveness. Nanoparticles can encapsulate curcumin, improving its solubility and facilitating targeted delivery to breast cancer cells, enhancing therapeutic efficacy.

2. **Neurological Disorders:**

Example: Ginkgo biloba extract nanoparticles for Alzheimer's disease.

Rationale: Ginkgo biloba is known for its neuroprotective effects. Nanotized formulations can improve the delivery of Ginkgo biloba extract to the brain, potentially aiding in the management of Alzheimer's disease by targeting specific pathways involved in neurodegeneration.

3. **Respiratory Conditions:**

Example: Nanotized Eucalyptus oil for respiratory health.

Rationale: Eucalyptus oil has respiratory benefits, but its direct application is limited. Nanoparticles carrying eucalyptus oil can be designed for targeted delivery to the respiratory system, aiding in conditions like asthma or COPD.

Sr. No.	Active phytochemical constituent	Biological Activity	Formulation	Method of preparation	Use
1	Paclitaxel	Antineoplastic	Paclitaxel loaded Nanoparticle	Emulsion solvent evaporative method Nanoprecipitation	Acts against several tumors, ovarian and breast cancer
2	Curcumin	Anticancer	Curcuminoids solid lipid nanoparticles	Micro-emulsion technique	Potent anticancer and antitumor
3	Ginko Biloba	Alzheimer's dementia	Combination of dry & wet process	Combination of dry and wet process	Acts against loss of memory, thinking, language and behavior
4	Silymarin	Hepatoprotective	Cold homogenization	Cold homogenization	Several liver disease and breast cancer

5	Camptothecin	Anticancer	Encapsulation with hydrophobically modified glycol	Encapsulated with hydrophobically modified glycol	Potent anticancer
6	Berberin	Anticancer	emulsion	Emulsion, Ionic gelation	Inflammation and several Cancers
7	Artemisinin	Anticancer	Artemisinin Nano capsule	Self-assembly procedure	Potent Anticancer

Ginko biloba as wound healing agent:-

Ginkgo biloba leaf extracts are widely used in the treatment of many diseases in alternative medicine. In recent years, it was found that Ginko Biloba can prevent various neurogenrative disorders, cerebralvascular disease, Alzheimer's disease, macroangiopathy and more. The main bioactive constituents are terpene trilactones and flavonoid glycosides which are responsible for the pharmacological activities of the standardized leaf extract. Other important constituents found in ginkgo include biflavonoids and traces of alkylphenols, such as ginkgolic acids. The aim of this work was development of solid lipid nanoparticles (SLNs) to be loaded with Ginkgo biloba extract and to be used as novel drug delivery system to enhance healing of wounds. Wound healing is a complex process with many potential factors that cause delay healing like bacterial and fungal. Using safe and effective antimicrobial compounds could accelerate the wound healing process.

Preparation of GBE- SLNS

GBE- SLNs were prepared by high pressure homogenization method. Briefly, 500 mg cholesterol as lipid matrix was added to the mixture of ethanol/acetone in ratio of 50/50 (%v/v) and the mixture heated at 50-60˚C under homogenization by homogenizer (MTOPS, SR30, Germany) at 500 round per minute (rpm). The desired amount of GBE is weighed and dispersed in 75ml deionized water containing 1% (w/v) Tween 80 as surfactant. The hot oily phase added drop wise to aqueous phase and homogenized at 11000-13000 rpm for 10 minutes. Then the mixture was sonicated for 2 minutes using ultrasonic system (LIRARE, ARSONIC60, Italy). After sonication, prepared mixture was centrifuged at 3000 rpm for 5 minutes to separate probable aggregates.

Freeze-drying of SLN

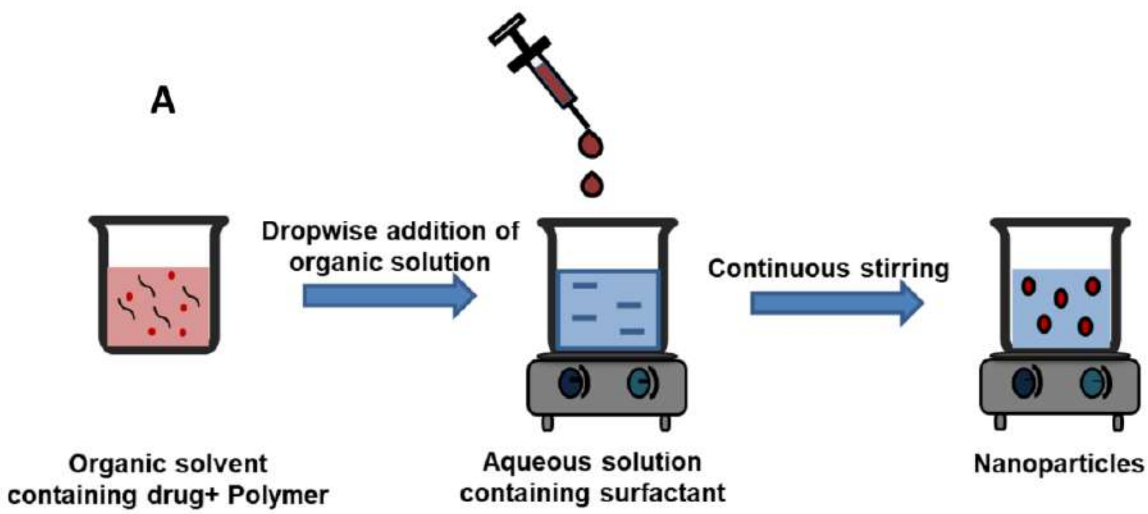
The selected particles (S7) were lyophilized to prolong the shelf life of GBE loaded SLNs. Lyophilization of particles was done using 5% (w/v) mannitol as cryoprotectant to limit the risk of particle aggregation. GBE-SLNs emulsion was frozen at -40˚C for 24 hours and then lyophilization was done.

Curcumin-loaded nanoparticles in the treatment of breast cancer.

Amongst different types of cancers, breast cancer is known to be the leading cause of morbidity and mortality in women with around 450,000 deaths around the world. Nanomedicine has received extensive interest in the journey of diagnostics and therapeutics owing to their small size, beneficial properties. Several polymers, such as poly (lactic-co-glycolic acid) (PLGA), poly (lactic acid) (PLA) etc. have been vividly used for cancer treatment, where few formulations also gained approval by regulatory agencies. Some of the nanotherapeutics used for the treatment of metastatic breast cancer are: Abraxane (albumin-based, paclitaxel nanoparticle formulation) In the study, a less investigated polymer called Poly-glycerol-malic acid- dodecanedioic acid (PGMD) was used for the preparation of formulations. The synthesis was done using the thermal condensation method by mixing glycol, malic acid and 1, 12-dodecanedioic acid (DDA). The polymer was non-toxic due to its naturally occurring by-products such as glycol, DDA and malic acid. Also, the glass transition temperature (Tg) and hydrophilicity can be adjusted by changing the ratio of malic acid and DDA during the synthesis procedure. [3]

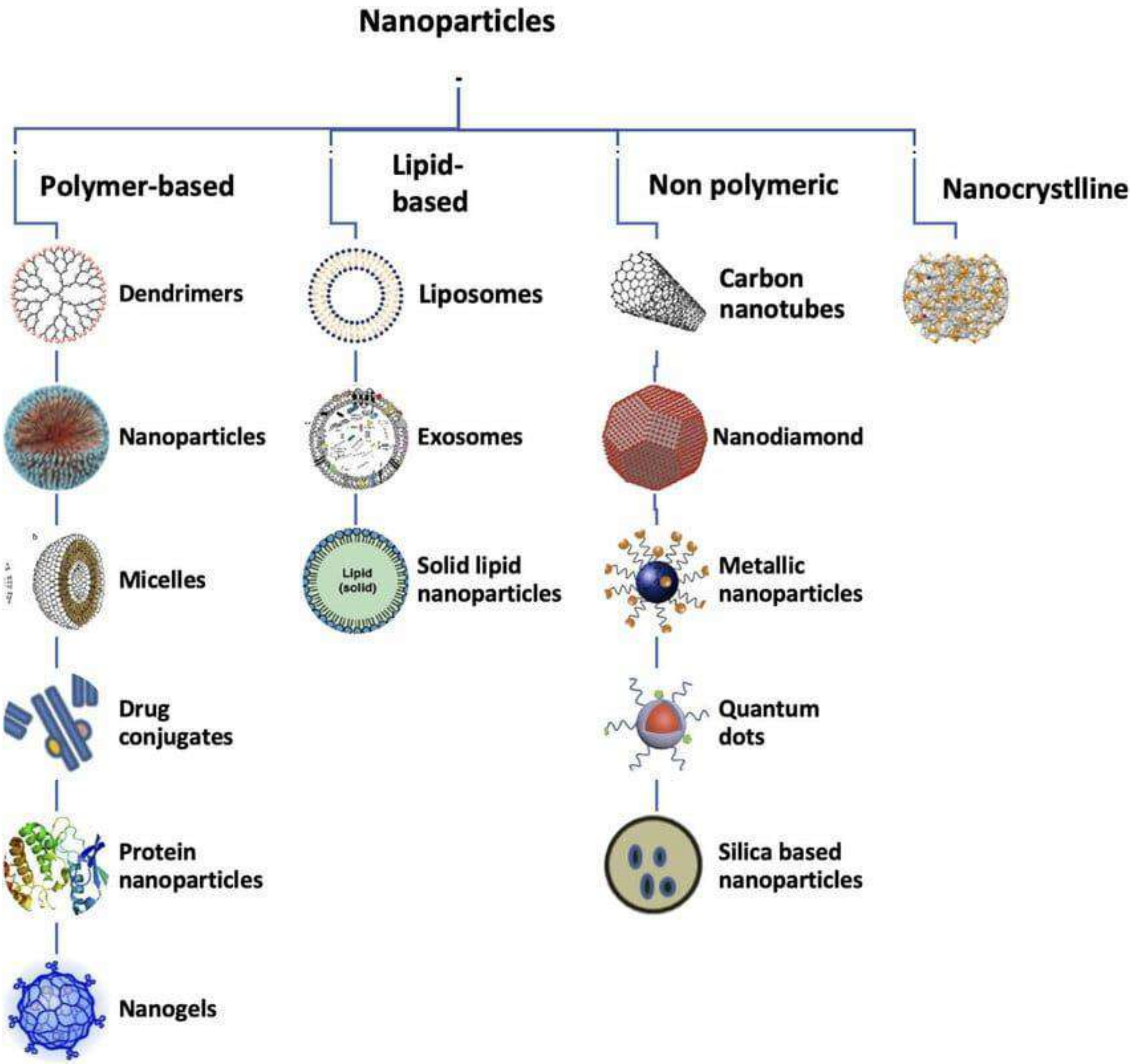
Synthesis of nanoparticles:-

Two variants of the polymer were synthesized by changing the molar ratio of DDA and malic acid (7:3 and 6:4). Briefly, DDA and malic acid were mixed at definite ratios in the presence of glycerol and heated up-to 120 °C for 48 h29. The synthesis of PGMD-CUR nanoparticles was done using the nanoprecipitation method. method involves precipitation of the polymer from organic to aqueous medium, generally in the presence of surfactant. However, the presence of a stabilizer such as poloxamer 127 is necessary in order to avoid aggregation during nanoparticle synthesis. Poloxamers, particularly, PF-127 is a non-toxic hydrophilic copolymer which is widely employed in pharmaceutical excipients due to its stabilizing properties and increased solubilization of drugs33. Briefly, 0.5 mg of the drug (curcumin) was dissolved in 0.5 mL acetone containing 5 mg polymer (PGMD) (Fig. 1A). The mixed solution was added dropwise to 5 mL 0.1% pluronic solution under stirring at 900 rpm (Stuart hotplate stirrer, UC152, Biocote). To organic phase was removed by leaving it under stirring for 24 h at room temperature.[3]



NANOTECHNOLOGY BASED DRUG DELIVERY SYSTEM FOR PHYTOCHEMICAL COMPOUNDS

According to study, approximately 70% of active ingredients from plants are hydrophobic, posing challenges for their bioavailability. New technologies, especially nanotechnology, are employed to enhance the bioavailability and bioactivity of phytochemical compounds. Following are the types of nanoparticles used in formulation of nanotechnology based herbal drug delivery system.



A. Polymer based :

1. Dendrimers:

Dendrimers are highly branched, well-defined, and symmetrical macromolecules with tree-like structures. They consist of a central core, branching units, and terminal functional groups.

Characteristics:

Highly Branched Structure: Dendrimers have a highly branched, tree-like architecture with multiple layers of branching.

Monodispersity: Dendrimers are monodisperse, meaning they have a well-defined size and molecular weight.

Multifunctionality:

Terminal functional groups and interior voids of dendrimers provide opportunities for functionalization, allowing for precise control over their properties.

Size and Shape Control:

The size and shape of dendrimers can be precisely controlled during their synthesis.

Spherical Symmetry:

Dendrimers often exhibit spherical symmetry, making them suitable for various applications, including drug delivery.

Applications:

Drug Delivery:

Dendrimers are utilized in drug delivery systems due to their ability to encapsulate drugs within their interior voids. Surface functionalization allows for targeted drug delivery and controlled release.

Biomedical Imaging:

Dendrimers can be modified with imaging agents for applications in diagnostics and medical imaging.

Gene Delivery:

Dendrimers serve as carriers for gene delivery, transporting genetic material into cells for gene therapy applications.

Catalysis:

Dendrimers can function as catalysts in various chemical reactions due to their unique architecture and multiple functional groups.

Sensors:

Dendrimers are employed in sensor technologies, benefiting from their well-defined structure and ability to interact with analytes.

Materials Science:

Dendrimers are used in materials science for the design of nanocomposites, polymers, and advanced materials with specific properties.

Antiviral Agents:

Some dendrimers exhibit antiviral properties and are explored as potential agents for inhibiting viral infections.

Photodynamic Therapy:

Dendrimers can be employed in photodynamic therapy by incorporating photosensitizers for targeted cancer treatment.

Coatings and Surface Modification:

Dendrimers can be used to modify surfaces or act as coatings to impart specific properties, such as biocompatibility or antimicrobial activity.

Dendritic Polymers:

Dendrimers can be used as building blocks in the construction of dendritic polymers with controlled architecture and properties.

Nanostructured Materials:

Dendrimers contribute to the development of nanostructured materials with applications in electronics, optics, and photonics.

Biotechnology:

Dendrimers find applications in biotechnology, such as the development of biosensors and drug delivery systems.

2. Miscelles:

Micelles are colloidal structures formed by the self-assembly of amphiphilic molecules in a solution. These molecules have both hydrophilic (water-attracting) and hydrophobic (water-repelling) regions. In an aqueous environment, amphiphilic molecules organize themselves to create micelles, which are spherical or ellipsoidal structures with the hydrophobic tails aggregated in the core, shielded by the hydrophilic heads. Here are key characteristics and applications of micelles:

Characteristics:

Amphiphilic Molecules: Micelles are formed by surfactant molecules or amphiphilic block copolymers with a hydrophilic head group and hydrophobic tail(s).

Critical Micelle Concentration (CMC):

Below a certain concentration known as the critical micelle concentration (CMC), individual surfactant molecules exist in the solution. Above the CMC, micelles start forming.

Size:

Micelles typically have sizes ranging from a few nanometers to tens of nanometers, depending on the nature of the amphiphilic molecules.

Core-Shell Structure:

The hydrophobic tails aggregate in the core of the micelle, creating a hydrophobic environment, while the hydrophilic heads face outward, interacting with the surrounding aqueous medium.

Dynamic Equilibrium:

Micelles are in dynamic equilibrium with individual surfactant molecules in the solution. They can disassemble and reform depending on the concentration of surfactants.

Applications:

Drug Delivery:

Micelles are used as drug delivery vehicles to solubilize hydrophobic drugs and enhance their bioavailability. The hydrophobic core of the micelle can encapsulate drugs, protecting them from degradation.

Cosmetics:

In cosmetics, micelles are employed in micellar water, which acts as a gentle cleanser for removing makeup and impurities. The hydrophobic core attracts and encapsulates oily substances.

Food Industry:

Micelles are utilized in the food industry for encapsulating and delivering certain flavors, colors, or nutrients. They can improve the solubility of hydrophobic additives.

Surfactant Applications:

Micelles play a crucial role as surfactants in various applications, such as emulsion stabilization, foaming, and detergent formulations.

Biomedical Imaging:

Micelles, especially those containing imaging agents, are used in biomedical imaging for contrast enhancement in techniques like magnetic resonance imaging (MRI) and fluorescence imaging.

Environmental Remediation:

Micelles are explored for environmental applications, including the removal of pollutants or contaminants from water through a process known as micellar enhanced ultrafiltration.

Polymerization:

Micelles can be involved in certain polymerization processes, especially in the synthesis of block copolymers, where micelles serve as templates for polymer growth.

Nanoreactors:

Micelles can function as nanoreactors for chemical reactions, providing a confined environment for specific reactions to occur.

DNA and RNA Delivery:

Micelles are studied for the delivery of nucleic acids, such as DNA or RNA, in gene therapy applications.

Photothermal Therapy:

Micelles can be designed to contain photothermal agents for applications in photothermal therapy, where localized heating is used to treat cancer.

3. Microemulion/Nanoemulsion

Microemulsions and nanoemulsions are colloidal systems consisting of small droplets of one immiscible liquid dispersed within another liquid. They are stabilized by surfactants and co-surfactants, forming a stable emulsion. Here are key characteristics and applications of microemulsions and nanoemulsions:

Microemulsion:

Droplet Size:

Microemulsions typically have larger droplet sizes, ranging from 100 to 1000 nanometers.

Appearance:

Microemulsions appear transparent or translucent, giving a clear appearance.

Stability:

Microemulsions are thermodynamically stable systems, maintaining their stability over an extended period.

Formation:

Microemulsions can spontaneously form without the need for high-energy input during their preparation.

Applications:

Commonly used in pharmaceuticals, food industry (for flavor encapsulation), and cosmetic formulations.

Solubilization:

Microemulsions are effective in solubilizing both hydrophilic and lipophilic compounds due to their larger droplet sizes.

Delivery Systems:

Used as delivery systems for drugs and other active ingredients due to their ability to improve bioavailability.

Nanoemulsion:

Droplet Size:

Nanoemulsions have smaller droplet sizes, typically below 100 nanometers, providing a higher surface area.

Appearance:

Nanoemulsions may appear translucent or opaque, depending on the droplet size and composition.

Stability:

Nanoemulsions are kinetically stable, and their stability is maintained by the presence of surfactants and co-surfactants.

Formation:

Nanoemulsions usually require high-energy methods, such as high-pressure homogenization or ultrasonication, for their preparation.

Applications:

Used in food and beverage industry for flavor delivery, in pharmaceuticals for drug delivery, and in cosmetic formulations.

Solubilization:

Nanoemulsions enhance the solubilization of lipophilic compounds due to their smaller droplet sizes.

Transdermal Delivery:

Nanoemulsions are explored for transdermal drug delivery, taking advantage of their small droplet sizes for improved skin penetration.

Agricultural Formulations:

Used in agriculture for the formulation of pesticides and herbicides to enhance their efficacy and stability.

Personal Care Products:

Incorporated into personal care products, such as lotions and creams, for improved stability and skin feel.

Nutraceuticals:

Nanoemulsions are utilized for the delivery of nutraceuticals and bioactive compounds in functional foods.

Parenteral Drug Delivery:

Nanoemulsions are investigated for parenteral drug delivery applications, aiming for improved drug solubility and bioavailability.

4. Nanosuspension

A nanosuspension is a colloidal dispersion of submicron-sized drug particles in a liquid medium, typically stabilized by surfactants or polymers. The small particle size in nanosuspensions enhances the drug's surface area, solubility, and dissolution rate, often leading to improved bioavailability. Here are key characteristics and applications of nanosuspensions:

Characteristics:

Particle Size:

Nanosuspensions consist of drug particles with sizes typically in the nanometer range, typically below 1 micron.

Stabilization:

Surfactants or polymers are used to stabilize the nanosuspension, preventing particle aggregation and ensuring long-term stability.

Improved Solubility:

Nanosuspensions are designed to address poorly water-soluble drugs by increasing their surface area, which enhances solubility.

Dissolution Rate:

The small particle size in nanosuspensions leads to a larger surface area, improving the drug's dissolution rate.

Homogeneity:

Nanosuspensions exhibit a high degree of homogeneity, ensuring uniform distribution of drug particles in the liquid medium.

Manufacturing Methods:

Common methods for preparing nanosuspensions include high-pressure homogenization, media milling, and precipitation techniques.

Applications:

Drug Delivery:

Nanosuspensions are used for drug delivery to improve the bioavailability of poorly soluble drugs, leading to enhanced therapeutic efficacy.

Oral Formulations:

Nanosuspensions are formulated for oral drug delivery, providing an effective means to enhance the absorption of poorly soluble drugs in the gastrointestinal tract.

Parenteral Formulations:

Nanosuspensions are explored for parenteral drug delivery, particularly for intravenous administration, where rapid dissolution is crucial.

Topical Formulations:

Used in topical formulations for skin delivery, providing improved skin penetration and drug release.

Ophthalmic Preparations:

Nanosuspensions are employed in ophthalmic formulations to enhance drug solubility and bioavailability for ocular delivery.

Inhalation Products:

Nanosuspensions can be adapted for inhalation formulations, improving the delivery of drugs to the respiratory system.

Cancer Therapy:

Nanosuspensions are explored for cancer therapy, delivering poorly water-soluble anticancer drugs to improve their therapeutic outcomes.

Antibiotic Formulations:

Nanosuspensions are used for formulating antibiotics, addressing issues of poor solubility and enhancing their effectiveness.

Vaccine Delivery:

Nanosuspensions are investigated for vaccine delivery, aiming to improve antigen stability and immune response.

Nutraceuticals: Used for the delivery of nutraceuticals and dietary supplements to improve their absorption and efficacy.

B. Lipid based:

1. Liposomes:

Liposomes are microscopic vesicles composed of lipid bilayers, typically phospholipids, that encase an aqueous core. These structures mimic cell membranes and have a wide range of applications in various fields.

Characteristics:

Structure:

Liposomes have a spherical or ellipsoidal structure with one or more lipid bilayers enclosing an aqueous core.

Amphiphilic Nature:

Phospholipids, the primary building blocks of liposomes, have hydrophilic ("water-loving") and hydrophobic ("water-fearing") regions, allowing liposomes to self-**assemble.**

Size Range:

Liposomes can vary in size from tens to hundreds of nanometers, depending on the method of preparation.

Biocompatibility:

Liposomes are biocompatible and can be composed of natural phospholipids, making them suitable for use in biological systems.

Encapsulation:

Liposomes can encapsulate both hydrophilic and hydrophobic substances within their aqueous core or lipid bilayers, allowing for the delivery of a variety of compounds.

Surface Modifications:

The surface of liposomes can be modified with various molecules, such as polyethylene glycol (PEG), to improve stability, circulation time, and target-specific delivery.

Applications:

Drug Delivery:

Liposomes are widely used as drug delivery vehicles. They can encapsulate drugs, improving their solubility, bioavailability, and targeted delivery to specific tissues or cells.

Vaccines:

Liposomes serve as carriers for vaccines, enhancing their stability and promoting controlled release of antigens, leading to an improved immune response.

Cosmetics:

Liposomes are employed in cosmetic formulations for the encapsulation and delivery of active ingredients. They enhance the penetration of substances into the skin, improving efficacy.

Genetic Delivery:

Liposomes are used in gene therapy to deliver genetic material, such as DNA or RNA, into cells. They protect the genetic material from degradation and facilitate its uptake by target cells.

Imaging Agents:

Liposomes can be loaded with contrast agents or imaging probes for diagnostic purposes. They improve the imaging contrast in techniques such as magnetic resonance imaging (MRI) or ultrasound.

Enzyme Delivery: Liposomes can encapsulate enzymes for targeted delivery in enzyme replacement therapy or other therapeutic applications.

Nutraceuticals:

Liposomes are used in the encapsulation and delivery of nutraceuticals, vitamins, and antioxidants. This enhances their stability and bioavailability.

Research Tools:

Liposomes are valuable tools in research for studying membrane dynamics, drug interactions, and cellular processes.

Antibody Delivery:

Liposomes can be conjugated with antibodies for targeted drug delivery to specific cells or tissues.

Infectious Disease Treatment: Liposomes are explored for the delivery of antimicrobial agents, particularly in the treatment of infections.

2. Niosomes:

Niosomes are vesicular structures similar to liposomes but composed of non-ionic surfactants and cholesterol. These self-assembled nanocarriers have a bilayer structure and an aqueous core, similar to liposomes.

Characteristics:

Composition:

Niosomes are primarily composed of non-ionic surfactants, such as Span and Tween, along with cholesterol. The combination of surfactants and cholesterol helps stabilize the vesicular structure.

Amphiphilic Nature:

Like liposomes, niosomes exhibit an amphiphilic nature, allowing them to self-assemble into bilayer structures in an aqueous environment.

Size Range:

Niosomes typically have sizes in the nanometer to micrometer range, depending on the formulation method.

Versatility:

Niosomes offer versatility in terms of composition and size, making them suitable for encapsulating both hydrophilic and hydrophobic substances.

Stability:

The presence of cholesterol in niosomes contributes to their stability, making them less susceptible to aggregation and fusion.

Biocompatibility:

Niosomes are generally considered biocompatible and are well-tolerated in biological systems.

Applications:

Drug Delivery:

Niosomes are used as drug delivery carriers, similar to liposomes. They can encapsulate a variety of drugs, improving their bioavailability, stability, and targeted delivery.

Cosmetics:

Niosomes find applications in cosmetics for the encapsulation and delivery of active ingredients, enhancing their skin penetration and efficacy.

Vaccines:

Niosomes can be employed as carriers for vaccine delivery, contributing to the development of stable and effective vaccine formulations.

Gene Delivery:

Niosomes are explored in gene delivery applications for the transportation of genetic material into cells.

Biomedical Imaging:

Niosomes can be loaded with imaging agents for diagnostic imaging applications, contributing to enhanced contrast in imaging modalities.

Nutraceuticals:

Niosomes are used for encapsulating and delivering nutraceuticals, vitamins, and antioxidants, improving their stability and bioavailability.

Antimicrobial Agents:

Niosomes are investigated for the delivery of antimicrobial agents, showing potential in the treatment of infections.

Topical Drug Delivery:

Niosomes are employed in topical drug delivery for skin diseases, providing controlled release of drugs to the affected area.

Enzyme Delivery:

Niosomes can encapsulate enzymes for targeted delivery in enzyme replacement therapy or other therapeutic applications.

Photodynamic Therapy:

Similar to liposomes, niosomes are explored in photodynamic therapy by encapsulating photosensitizers for targeted cancer treatment.

Research Tools:

Niosomes serve as research tools for studying membrane dynamics, drug interactions, and cellular processes, similar to liposomes.

C. Non-polymeric:

1. Gold nanoparticles:

Gold nanoparticles are nanoscale-sized particles composed of gold atoms. They exhibit unique physical and chemical properties due to their small size and high surface area-to-volume ratio.

Characteristics:

Size Range:

Typically, gold nanoparticles have diameters ranging from 1 to 100 nanometers.

Color:

The color of gold nanoparticles can vary from red to purple, depending on their size and shape. This phenomenon is known as surface plasmon resonance

Stability:

Gold nanoparticles are stable and inert, making them suitable for diverse applications.

Application:

Biomedical Imaging:

Gold nanoparticles are used in imaging techniques such as computed tomography (CT) scans. Their unique optical properties enhance contrast in imaging, aiding in the visualization of tissues and cells.

Drug Delivery:

Gold nanoparticles can serve as carriers for drug delivery due to their biocompatibility. Surface modifications enable targeted drug delivery to specific cells or tissues.

Cancer Treatment:

Gold nanoparticles can be employed in photothermal therapy, where they absorb light and convert it into heat, selectively destroying cancer cells. They are also used in radiotherapy to enhance the treatment's effectiveness.

Diagnostic Assays:

Gold nanoparticles are utilized in various diagnostic assays, such as lateral flow assays and biosensors. They provide a visible signal when binding to specific biomolecules, facilitating rapid and sensitive detection.

Catalysis: Gold nanoparticles exhibit catalytic activity in certain reactions. They are employed in catalysis for the synthesis of various organic compounds.

Electronic and Optical Devices:

Gold nanoparticles find applications in electronics, particularly in the development of nanoscale electronic devices.They are used in the fabrication of nanoscale optical components and sensors.

Photo-thermal Therapy:

Gold nanoparticles can absorb light in the near-infrared region, making them suitable for photothermal therapy.In this application, they generate heat to selectively destroy cancer cells.

Antimicrobial Applications:

Gold nanoparticles have demonstrated antimicrobial properties and are investigated for potential use in combating infections.

2. Magnetic nanoparticle:

Magnetic nanoparticles are nanoscale-sized particles that exhibit magnetic properties. These particles are typically composed of magnetic materials such as iron, cobalt, nickel, or their alloys.

Characteristics:

Size Range:

Magnetic nanoparticles typically have diameters ranging from a few to several hundred nanometers. Magnetic Properties: Magnetic nanoparticles possess magnetic moments, allowing them to respond to external magnetic fields.

Superparamagnetism:

At the nanoscale, these particles often exhibit superparamagnetism, meaning they become magnetized in the presence of an external magnetic field and lose magnetization when the field is removed

Application:

Biomedical Imaging:

Magnetic Resonance Imaging (MRI): Magnetic nanoparticles are used as contrast agents in MRI to enhance the visibility of tissues and improve imaging quality.

Magnetic Particle Imaging (MPI):

A novel imaging technique that utilizes the magnetic properties of nanoparticles for high-resolution imaging.

Drug Delivery:

Magnetic nanoparticles can be employed as carriers for drug delivery. External magnetic fields guide and concentrate drug-loaded nanoparticles to specific target sites, improving therapeutic efficiency and reducing side effects.

Hyperthermia Treatment:

Magnetic nanoparticles can generate heat when exposed to an alternating magnetic field. This property is utilized in hyperthermia treatment for cancer therapy, where localized heating damages cancer cells.

Environmental Remediation:

Magnetic nanoparticles can be used for environmental cleanup by removing pollutants from water or soil. They can be functionalized to selectively bind to contaminants, facilitating their removal.

Magnetic Separation:

Magnetic nanoparticles are employed in magnetic separation processes for the purification of biological samples, water treatment, and separation of biomolecules.

3. Ceramic Nanoparticles:

Ceramic nanoparticles are nanoscale-sized particles composed of ceramic materials. These materials are typically inorganic compounds, and the nanoparticles exhibit unique properties compared to their bulk counterparts.

Characteristics:

Size Range:

Ceramic nanoparticles typically have diameters ranging from 1 to 100 nanometers.

Surface Area:

The high surface area-to-volume ratio of ceramic nanoparticles contributes to their unique properties and reactivity.

Enhanced Properties:

At the nanoscale, ceramics may exhibit enhanced mechanical, electrical, and thermal properties compared to their larger counterparts.

Optical Properties:

Some ceramic nanoparticles exhibit interesting optical properties, making them useful in various applications, including sensors and imaging.

Applications:

Electronics:

Ceramic nanoparticles are used in the fabrication of electronic components and devices. They contribute to the development of advanced materials for semiconductors and electronic circuits.

Catalysis:

Certain ceramic nanoparticles act as catalysts in chemical reactions. They provide a high surface area for catalytic reactions, contributing to the efficiency of the process.

Biomedical Applications:

Ceramic nanoparticles find applications in biomedical fields. They may be used in drug delivery systems, imaging agents, and as components in bone tissue engineering.

Coatings and Films:

Ceramic nanoparticles are incorporated into coatings and films for various applications. They enhance the properties of materials, such as hardness, wear resistance, and corrosion resistance.

Sensors:

Ceramics with specific electronic and sensing properties are used in the development of sensors. Ceramic nanoparticles contribute to the sensitivity and selectivity of sensors for various applications.

Ceramic Nanocomposites:

Incorporating ceramic nanoparticles into polymers or metals forms nanocomposites with improved mechanical and thermal properties. These nanocomposites find applications in aerospace, automotive, and structural materials.

Energy Storage:

Ceramic nanoparticles play a role in energy storage devices, such as batteries and capacitors. They contribute to improved performance and efficiency in these energy storage systems.

4. Carbone nano tubes

Carbon nanotubes (CNTs) are cylindrical structures made up of carbon atoms arranged in a hexagonal lattice. They exhibit remarkable mechanical, electrical, and thermal properties, making them a subject of extensive research in various fields.

Characteristics:

Structure:

Carbon nanotubes can have single-walled or multi-walled structures, with the carbon atoms arranged in a hexagonal lattice.

Length and Diameter:

Carbon nanotubes can have lengths ranging from nanometers to centimeters and diameters as small as one nanometer.

Electrical Conductivity:

Carbon nanotubes demonstrate exceptional electrical conductivity due to the sp2 hybridized carbon atoms in their structure.

Mechanical Strength:

Carbon nanotubes possess extraordinary mechanical strength and stiffness, exceeding that of many materials, including steel.

Thermal Conductivity:

They exhibit high thermal conductivity, making them efficient heat conductors.

Lightweight:

Carbon nanotubes are lightweight yet incredibly strong, making them valuable for structural applications.

Chemical Stability:

Carbon nanotubes exhibit high chemical stability, especially when they have a closed end.

Applications:

Nanocomposites:

Carbon nanotubes are incorporated into polymer matrices to create nanocomposites with enhanced mechanical and electrical properties.

Electronics:

CNTs are used in electronics for developing high-performance transistors, flexible electronics, and conductive films.

Energy Storage:

Carbon nanotubes are explored for applications in energy storage devices, including batteries and supercapacitors, due to their excellent electrical conductivity.

Sensors:

CNTs are employed in sensor technologies for detecting gases, biomolecules, and various analytes with high sensitivity.

Field Emission:

Carbon nanotubes are utilized in field emission applications, where they serve as efficient electron emitters in devices like cathode-ray tubes.

Medical Applications:

In medicine, CNTs are investigated for drug delivery, imaging, and as scaffolds for tissue engineering.

Aerospace Materials:

Due to their lightweight and strong properties, carbon nanotubes are used in the development of lightweight and strong materials for aerospace applications.

Thermal Management:

Carbon nanotubes are employed in thermal interface materials to enhance the thermal conductivity of electronic devices for efficient heat dissipation.

Water Purification:

CNTs are explored for water purification applications, acting as efficient filters for removing pollutants and contaminants.

Coatings:

Carbon nanotubes are used in coatings to enhance conductivity, mechanical strength, and corrosion resistance.

Catalysis:

CNTs can serve as catalyst supports in various catalytic processes due to their large surface area and unique properties.

Flexible Electronics:

Carbon nanotubes are used in the development of flexible and stretchable electronics, such as flexible displays and sensors.

Photodetectors:

CNT-based photodetectors are developed for sensing light in various applications, including imaging and communication devices

5. Nanopores

Nanopores are tiny openings or cavities on the nanoscale, typically ranging from one to several nanometers in diameter. These structures can be found naturally in biological systems or can be artificially created for various applications.

Characteristics:

Size:

Nanopores have dimensions on the nanometer scale, allowing the passage of molecules or ions through the pore.

Material:

Nanopores can be made from various materials, including biological molecules (e.g., proteins, DNA), solid-state materials (e.g., graphene, silicon), or synthetic polymers.

Shape:

Nanopores can have different shapes, such as cylindrical, conical, or irregular, depending on their fabrication method and intended use.

Functionality:

The functionality of nanopores can vary. For example, biological nanopores may play a role in cellular processes like ion transport or DNA sequencing, while synthetic nanopores may be engineered for specific applications.

Applications:

DNA Sequencing:

Nanopores are utilized in DNA sequencing technologies, where individual DNA strands pass through the pore, and the resulting electrical signals are used to determine the DNA sequence.

Protein Analysis:

Nanopores can be employed for the analysis of proteins, enabling the study of their structure, folding, and interactions.

Ion Transport:

Biological nanopores, such as those found in cell membranes, are involved in ion transport processes crucial for cellular functions.

Single-Molecule Sensing:

Nanopores are used in single-molecule sensing applications, allowing the detection and analysis of individual molecules passing through the pore.

Drug Delivery:

Synthetic nanopores are investigated for drug delivery applications, providing controlled release of drugs at the nanoscale.

Separation and Filtration:

Nanopores are employed in separation and filtration processes, such as in water purification or the separation of nanoparticles based on size.

Sensor Devices:

Nanopores serve as the basis for developing sensor devices, including gas sensors, biosensors, and chemical sensors.

Electronics:

Nanopores are explored for applications in nanoelectronics, offering potential uses in transistors and other electronic devices.

Energy Storage:

Nanopores play a role in energy storage devices, such as supercapacitors, where they contribute to efficient ion transport.

Catalysis:

Nanopores can be utilized in catalytic processes, providing confined spaces for specific chemical reactions.

Molecular Dynamics Studies:

Nanopores are used in molecular dynamics simulations to study the behavior of molecules at the nanoscale.

Biomedical Diagnostics:

Nanopores are explored for applications in biomedical diagnostics, including the detection of biomarkers and disease-related molecules.

Optical Devices:

Nanopores can be incorporated into optical devices for applications in photonics and optics.

D. Nanocrystalline:

1. Nanocrystals

Nanocrystals refer to nanoscale-sized crystalline particles, typically ranging from a few nanometers to a few hundred nanometers in size. These nanosized crystals can be composed of various materials, including organic or inorganic substances. Here are key characteristics and applications of nanocrystals:

Characteristics:

Size:

Nanocrystals have dimensions in the nanometer range, exhibiting a high surface area-to-volume ratio.

Crystallinity:

Nanocrystals are characterized by their crystalline structure, with well-defined lattice arrangements at the atomic or molecular level.

Stabilization:

Stabilizers or surfactants are often used to prevent agglomeration and maintain the stability of nanocrystals.

Shape:

Nanocrystals can have various shapes, including spheres, rods, cubes, or other geometric forms, depending on the synthesis method.

Surface Properties:

The surface properties of nanocrystals play a crucial role in their reactivity, stability, and interaction with surrounding environments.

Applications:

Drug Delivery:

Nanocrystals are utilized in drug delivery to enhance the solubility and bioavailability of poorly water-soluble drugs, improving therapeutic efficacy.

Pharmaceuticals:

Nanocrystals find applications in the pharmaceutical industry for formulating oral and parenteral drug products with improved drug release characteristics.

Catalysis:

Nanocrystals are employed as catalysts in various chemical reactions due to their high surface area and enhanced reactivity.

Electronics:

In electronics, nanocrystals are used for the development of nanoelectronic devices, quantum dots, and other electronic components.

Optoelectronics:

Nanocrystals, especially semiconductor nano-crystals or quantum dots, are used in optoelectronic devices for applications like LEDs and solar cells.

Magnetic Materials:

Magnetic nanocrystals are applied in the development of magnetic materials for data storage, magnetic resonance imaging (MRI), and other applications.

Photocatalysis:

Nanocrystals are employed as photocatalysts for various reactions, harnessing their photoactive properties.

Biomedical Imaging:

Quantum dots and other nanocrystals are used as contrast agents for biomedical imaging techniques, providing enhanced resolution.

Sensors:

Nanocrystals are incorporated into sensor devices for their sensitivity to environmental changes or specific analytes.

Energy Storage:

Nanocrystals are investigated for applications in energy storage devices, such as batteries and supercapacitors, due to their unique properties.

Photovoltaics: Nanocrystals are used in the development of solar cells to enhance light absorption and improve energy conversion efficiency.

Cosmetics:

Nanocrystals find applications in cosmetics for their ability to improve the texture and appearance of skincare products.

Coatings:

Nanocrystals can be used in coatings to impart specific properties, such as enhanced durability, scratch resistance, or antimicrobial effects.

Food Industry:

Nanocrystals may be used in the food industry for improving the stability and delivery of certain food additives or nutraceuticals.

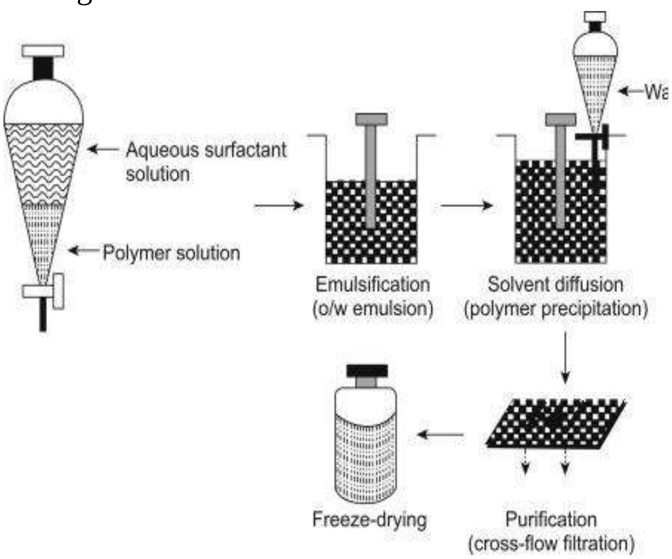
TECHNIQUES FOR PREPRATION OF NANOPARTICLES

1. High pressure homogenization method

High-pressure homogenizers consist of a pump that forces the material through a narrow gap at high pressure.Initial Homogenization: The substance to be homogenized, often a liquid or suspension, is pumped through a valve or a small orifice, causing high-pressure turbulence.Cavitation and Shear Forces: The material experiences intense shear forces and cavitation as it passes through the small gap, breaking down larger particles into smaller ones.Recirculation: The processed material is often recirculated through the homogenizer multiple times to achieve the desired level of particle size reduction.Final Homogenization: The repeated high-pressure cycles result in a more uniform and fine dispersion of particles or droplets.

2. Salting Out/Emulsion Diffusion Method

In this method, water-soluble polymers are dissolved in a highly concentrated solution of electrolytes or nonelectrolytes to obtain a viscous gel (aqueous phase). This aqueous gel is added to an organic phase such as acetone to obtain an oil-in-water emulsion under vigorous stirring. The formation of nanoparticles is facilitated by adding an excess amount of water, which diffuses the acetone out. The residual organic solvent is removed by continuous stirring or high-speed homogenization.

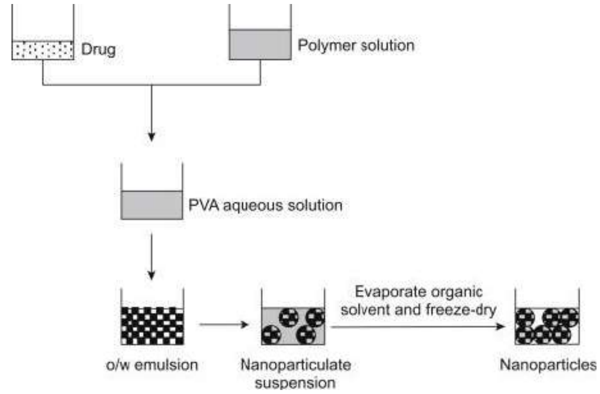


3. **Spontaneous Emulsification/Solvent Diffusion Method**

This is a modification of the solvent evaporation technique. In this method, water-miscible solvents such as acetone or methanol are used as the organic phase I and water immiscible solvents such as dichloromethane or chloroform are used as the organic phase II. The interfacial turbulence that is created when these two phases are mixed leads to the formation of nanoparticles. Even though this method produces significantly smaller sized particles, there are some disadvantages such as the presence of residual organic solvent.

4. **Solvent Evaporation Method**

In this method the preformed polymers such as polyl-actic acid or poly (d,l-lactic co-glycolic acid) are dissolved in an organic solvent such as chloroform, acetone, or ethyl acetate.

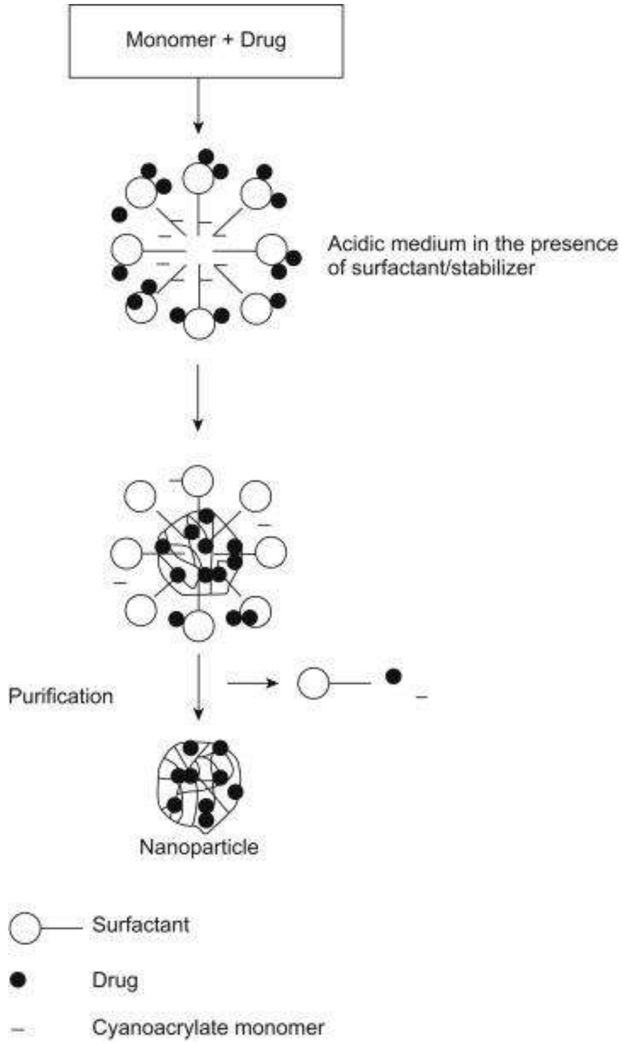


5. **Nonaqueous Phase Separation Method**

This method is suitable for both hydrophilic and lipophilic drugs [90]. Generally, the hydrophilic drugs are dissolved in water and then added to the organic phase. On the other hand, the lipophilic drugs are dissolved in a polymer solution. Once the aqueous phase and organic phase are mixed to form an emulsion, a second organic nonsolvent such as silicone oil (which is miscible with the first organic phase but does not dissolve the drug) is added under vigorous stirring. This results in the extraction of the first organic solvent, which causes the decrease in the solubility of polymer followed by phase separation and formation of a polymer coacervate. This polymer coacervate adsorbs onto the drug molecules to form drug-loaded nanoparticles.

6. **Nanoparticle Preparation by the Emulsion Polymerization Method**

In this method, monomers such as polyalkylcyanoacrylates are mechanically polymerized in the presence of drug to obtain drug-loaded nanoparticles. Initially the monomers are dispersed in an aqueous acidic medium in the presence of a surfactant and stabilizing agent such as polysorbate 20. The drug can be added to the surfactant solution before or at the end of the polymerization process. The mechanism of polymerization has been explained schematically in Fig Initially, the nonpolar tail ends of surfactant micelles dissolve monomers when they are added to the aqueous acidic medium in the presence of the surfactant and stabilizer solution. Anions such as OH-, CH3O-, and CH3COO- initiate the polymerization process. The monomer molecules enter the core of the surfactant micelles to continue the polymerization process. The polymerization process is favorable between pH 1.5–3. This ensures the stability of the nanoparticles as well. The process of nanoparticle formation is facilitated by mechanical stirring. The resultant nanoparticles are collected by ultracentrifugation and finally dispersed in a surfactant-free me4dium.



CHARACTERIZATION OF NANOPARTICLES

Characterization is studying the physical, chemical, composition and the structure of the material. Nanoparticles are generally characterized by their size, morphology and surface charge, using advanced microscopic techniques. The techniques are as follows:

1. Particle size analyzer

The technique is ideally suited for the determination of the size of particles in the nanometer size range. The major application of nanoparticle is in drug release and drug targeting. ISeveral methods are commonly employed by particle analyser. Some of the specific methods suitable for nanoparticle sizing include:

- Nanoparticle tracking analysis
- Transmission electron microscopy
- Cryogenic transmission electron microscopy.
- Small angle X-ray
- Resonant mass measurement

2. Surface area analysis

Surface area analysis of nanoparticles is often conducted using methods such as the Brunauer-Emmett-Teller (BET) method, which you mentioned earlier. The following steps are in the process:

- Adsorption of Gas: Nanoparticles are exposed to a gas (commonly nitrogen) at various pressures and temperatures.
- Multilayer Adsorption: The gas molecules form layers on the nanoparticles' surfaces. The BET method relies on the formation of multilayer adsorption.
- Measurement of Gas Adsorption: The quantity of adsorbed gas is measured at different pressures, forming an adsorption isotherm.
- BET Equation: The BET equation is applied to the isotherm data, allowing for the calculation of the specific surface area of the nanoparticles.

3. Spectroscopic Analysis (UV- Visible Spectroscopy)

UV/Visible spectroscopy is a technique used to quantify the light that is absorbed and scattered by a sample. In its simplest form, a sample is placed between a light source and a photodetector, and the intensity of a beam of UV/visible light is measured before and after passing through the sample. Gold and silver plasmonic nanoparticles have optical properties that are sensitive to size, shape, concentration, agglomeration state, and refractive index near the nanoparticle surface, which makes UV/Vis spectroscopy a valuable tool for identifying, characterizing, and studying nanomaterials.

4. Dynamic light scattering

Dynamic Light Scattering (DLS) is an important tool for characterizing nanoparticles and other colloidal solutions. DLS measures light scattered from a laser that passes through a colloidal solution. By analyzing the modulation of the scattered light intensity as a function of time, information can be obtained on the size of the particle in solution. When a laser light falls on a solution of particles with continuous Brownian motion causes a Doppler shift resulting in change in the wavelength of incident light.

5. Transmission electron microscope

In this method the dispersion of sample nanoparticle is deposited onto support grids or films. To withstand instrument vacume the nanoparticles are fixed using negative staining material, such as phosphor tungstic acid or derivative. The surface characteristics of the sample are obtained when a beam of electron is transmitted through an ultra-thin sample, interacting with the sample as it passes through.

6. Atomic force microscopy

It offers ultra-high resolution in particle size measurement and is based on physical scanning of samples at a sub-micron level using a probe tip of atomic scale. Their are two modes in which the samples are scanned.

- Contact mode
- Non-contact mode

In contact mode the topographical map is generated by tapping the probe on to the surface across the sample and probe hovers over the conducting surface in non-contact mode. The prime advantage of AFM is its ability to image non-conducting samples without any specific treatment, thus allowing imaging of delicate biological and polymeric nano and microstructures. AFM provides the most accurate description of size and size distribution and requires no mathematical treatment.

RECENT DEVELOPMENTS

As updated the nanotechnology has best approach in drug delivery system. Including the drug targeting, drug release profile, drug modifying, etc. For the treatment of various diseases such as cancer, rheumatoid artheritis, hepatic disorder, alzimeres, dementia, etc the technology is used at a large scale. Currently, the pharmaceutical scientists have shifted towards designing a drug delivery system for herbal medicine using a scientific approach. The roots of plant Pueraria lobata has broad pharmacological activity for diseases like cardiovascular disease, diabetes, osteonecrosis, parkinson's disease, Alzheimer disease, endometriosis and cancer. Puerarin is the main chemical constituent obtained from the roots. It has low water solubility in water but has maximum solubility in phosphate buffer of PH 7.4. The low solubility limits application of puerarin. In recent years, research on increasing the bioavailability of puerarin has grown rapidly. Various nanotechnology has been investigated to increase the bioavailability of puerarin, one of which is the solid lipid nanoparticle (SLN) carrier system. Compared to puerarin suspension, SLN-puerarin is absorbed rapidly. This is supported by a shorter Tmax. In addition, SLN-puerarin showed mopre than threefold bioavailability compared to puerarin suspension. A recent experimental study of polylactic acid nanoparticles of lipophilic anti-cancer herb drug (Cucurbitacins and Curcuminoids) using a precipitation method have been developed In the recent years, nanostructured carrier system like polymeric nanoparticles, liposomes, SLNs, polymeric micelles, nanoemulsions, etc., have been investigated for their potential to deliver anticancer drugs by oral route. Moreover, the oral route offers great potential for delivery of cytotoxic agents and therefore the attention has focused on the development of oral chemotherapy in oncology.

TOXICITY ISSUES

While nanotechnology offers promising applications in herbal drug systems, it's crucial to consider potential toxicity issues associated with the use of nanoparticles. Some key concerns include:

1. **Biocompatibility:**

Nanoparticles may exhibit different biological behaviors compared to larger particles. Assessing the biocompatibility of nano-materials with biological tissues is essential to avoid adverse reactions.

2. Accumulation and Bio-distribution:
Nanoparticles can accumulate in organs or tissues, potentially leading to long-term effects. Understanding the bio-distribution patterns is critical for evaluating safety.

3. Potential for Nanoparticle Toxicity:
Certain nanoparticles, especially those made from metals or metal oxides, may pose toxicity risks. The release of ions or reactive oxygen species can induce cellular damage.

4.Immunological Responses:
Nanoparticles may trigger immune responses, leading to inflammation or hypersensitivity reactions. The immune system's reaction to the nanoparticles should be thoroughly investigated.

5. **Genotoxicity:**

Evaluation of potential genotoxic effects is crucial. Nanoparticles may interact with genetic material, leading to DNA damage or other genomic alterations.

6. **Environmental Impact:**

Considering the eventual disposal of nanoparticle-containing products, assessing their environmental impact is essential. Nanoparticles may pose risks to ecosystems and aquatic life.

7. **Interactions with Herbal Compounds:**

The interaction between nanoparticles and herbal compounds should be studied to ensure that the combined formulation does not lead to unforeseen toxic effects.

FUTURE PERSPECTIVE OF NANOTECHNOLOGY BASED HERBAL DRUG MEDICINE

In all over the world various research and development programs are taking place on herbal medicines. Number of institutes, organizations are busy with the development of herbal medicine in the such drug delivery system which is more potent and gives best effect as required. In future, the concept of herbal nanoparticles for cancer drug delivery may also fascinate some potential research groups and potentially create attention grabbing results.

The future perspective of nanotechnology in herbal drug development holds exciting possibilities. Some anticipated trends and areas of focus include:

- **Precision Herbal Medicine:**

Nanotechnology enables targeted delivery of herbal compounds to specific cells or tissues, enhancing therapeutic precision and minimizing side effects.

- **Personalized Medicine:**

Advancements in nanotechnology may contribute to the development of - personalized herbal medicine, tailoring formulations based on an individual's genetic makeup, health status, and specific needs.

- **Synergistic Formulations:**

Combining nanotechnology with systems biology may lead to the creation of synergistic herbal formulations, optimizing the therapeutic effects of multiple compounds.

- **Biosensors for Monitoring:**

Integration of nanoscale biosensors may allow real-time monitoring of the therapeutic response, facilitating adaptive treatment strategies and improved patient outcomes.

- **Enhanced Diagnostics:**

Nanotechnology may contribute to the development of advanced diagnostic tools for assessing herbal product quality, authenticity, and ensuring standardized formulations.

- **Combination Therapies:**

Further exploration of synergies between herbal nanoparticles and conventional drugs, leading to the development of effective combination therapies for complex diseases.

- **Green Nanotechnology:**

Continued emphasis on sustainable and environmentally friendly approaches, promoting the use of green nanotechnology methods for synthesizing herbal nanoparticles.

CONCLUSION

Overall the review indicates the nanotechnology has great potential to deliver herbal drugs and nutraceuticals. Nanotechnology has property of self-targeting in the sence without the attachment of a specific ligand, the nanoparticle can be used for targeting, due to their small size. It supports to transport herbal drugs for better treatment. In the present times, the nanotechnology has gain more attention because of their targeted treatment and reduced possibility of toxicities and infections. Different techniques practiced ain nanoparticles and the classification of nanoparticle have been widely evaluated. With the application of nanotechnology of nanomization of herbal drugs, it will make the development of nano-herbal drugs possessing high bioavailability, which consequently will open the new era of herbal drug discovery. At present, several nano drugs are under investigation for drug delivery and more specifically for cancer therapy.

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