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A REVIEW ON NANOFORMULATION IN DRUG DELIVERY

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Abstract:

Nanoformulation is a modern drug delivery strategy designed to enhance the solubility, stability, bioavailability, and therapeutic efficacy of drugs, particularly those with poor water solubility. Nanocarriers such as liposomes, polymeric nanoparticles, nanoemulsions, dendrimers, and metallic nanoparticles have demonstrated significant potential in targeted and controlled drug delivery. This review highlights the classification, advantages, applications, limitations, and future prospects of nanoformulations in pharmaceutical sciences. Nano- details support the properties of traditional measurement structures and show focused on conveyance approach. Nano-plans, for example, polymeric nanoparticles, dendrimers, nanoemulsions, liposomes, micelles and nanosuspension are of enthusiasm for some specialists for sedate conveyance system. Different techniques for combination are accessible for the planning of nano definitions to convey medicates in natural framework and selection of strategies rely upon the biochemical properties of medication, size and state of particulate detailing, and the focused in the vicinity. Current audit article examines nano definition and their strategy for readiness with its application in detail

Keywords: *Nanoformulation, Drug delivery, nanoparticles, Liposomes, Nanoemulsion,Targeted ,application*

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INTRODUCTION:

Advances in innovation has prompted improvement in pharmaceutical measurement structure from basic framework to exceptionally modern ones, alluded as novel medication conveyance framework.[1] As of late the advancement in novel medication conveyance framework has been begun for improving restorative estimation of therapeutic medications. Medication conveyance plan has increased gigantic development by the improvement of nanotechnology

In recent years, nanotechnology has emerged as a revolutionary approach in the pharmaceutical sciences. Nanoformulations involve the use of nanocarriers such as nanoparticles, liposomes, nanoemulsions, dendrimers, and micelles to deliver drugs efficiently. They can bypass biological barriers, provide site-specific delivery, and improve patient compliance

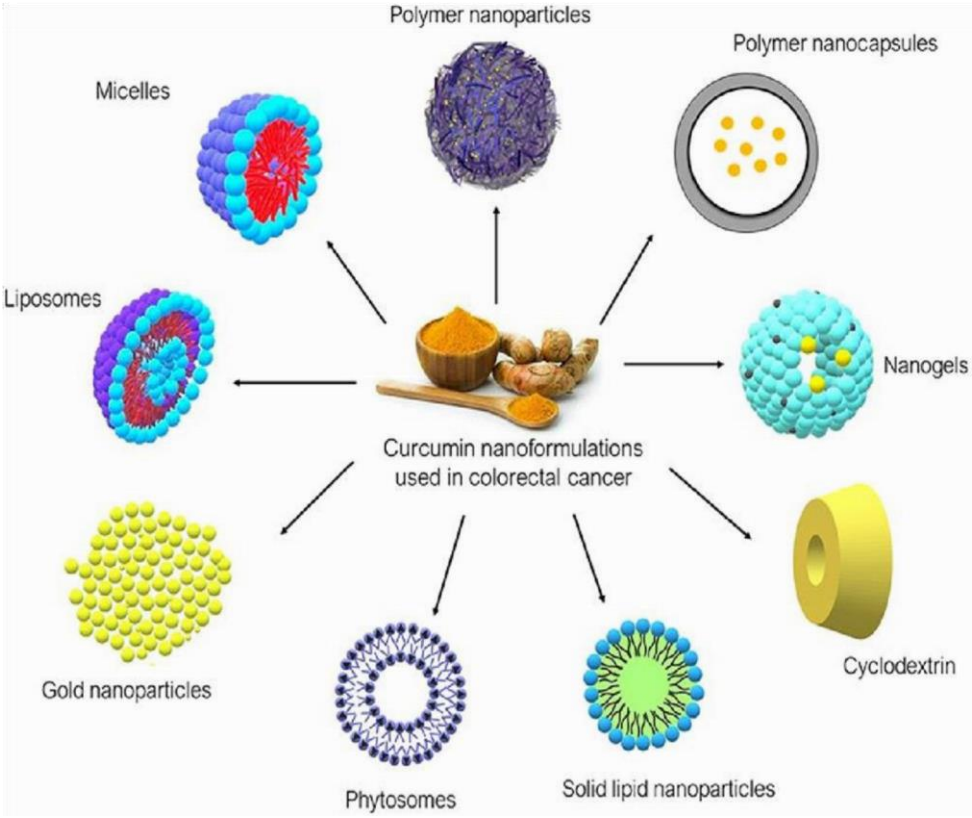

FIG NO 1. CURCUMIN NANOFORMULATION FOR COLORECTAL CANCER

Nanoformulations involve the design and development of drug delivery systems at the nanoscale

(1–100 nm), which improves solubility, stability, and therapeutic efficacy of drugs. With the increasing prevalence of poorly water-soluble drugs, nanoformulations offer a solution to enhance absorption, reduce side effects, and target specific tissue es or cells.

Different nano- definitions have been utilized in tranquilize conveyance research to improve focused on medicate conveyance framework, its bioavailability, dissolvability, sedate maintenance time alongside limiting their reaction including harmfulness.[2-3]

Nanotechnology has been acquainted with take care of the issues related with improving solvency and bioavailability. The presentation of medication relies on its intensity as well as on through which measurements structure it is administered. Various nano-plans, for example, polymeric nanoparticles, dendrimers, liposomes, nano-emulsions, micelles and nanosuspension are utilized in the pharmaceutical business for sedate conveyance framework.

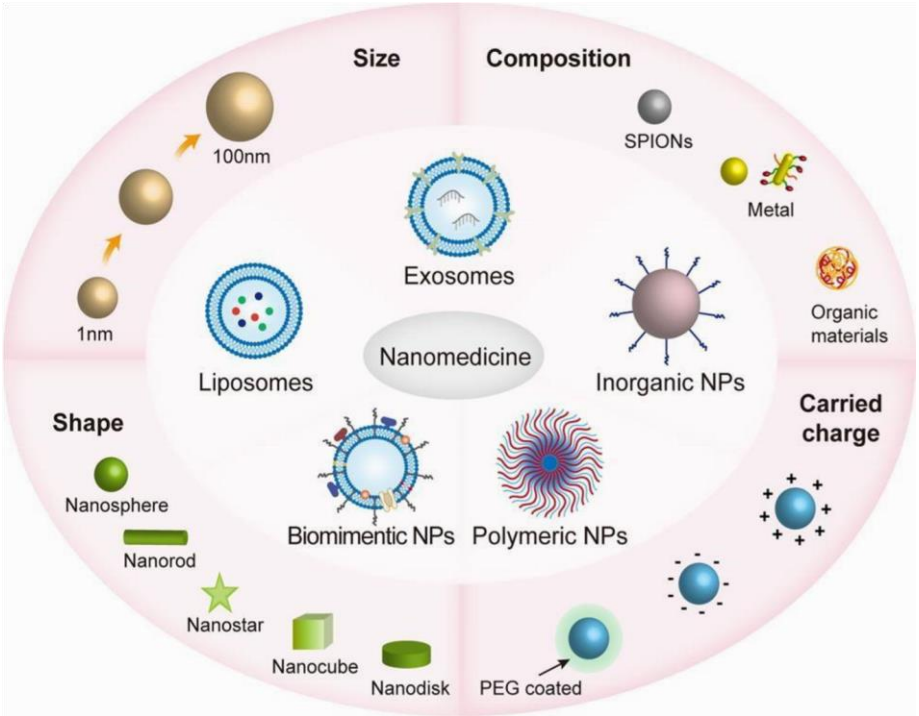

FIG NO 2. NANOFORMULATION FOR TARGETED DRUG DELIVERY SYSTEM

Nanosuspension comprises of submicron colloidal scattering of medication particles. A pharmaceutical nanosuspension is characterized as finely colloid, biphasic, scattered strong medication particles in a watery vehicle having size beneath 1 µm joining surfactants and polymers arranged by reasonable techniques for tranquilize conveyance applications. Different nano- definitions have been utilized in tranquilize conveyance research to improve focused on medicate conveyance framework, its bioavailability, dissolvability, sedate maintenance time alongside limiting their reaction including harmfulness. Numerous photochemical which are utilized as medication are exceptionally water-dissolvable yet lower assimilation properties due powerlessness to pass lipid layer alongside high atomic weight. Over 40% new medication are poor water dissolvable having low medication assimilation which brings about low bioavailability and inefficacy in tranquilize conveyance consequently further prompts diminished remedial movement. The significant explanation for the poor ingestion of such medication is because of issue related in finding fitting ideal detailing to represent physiochemical properties of the medication, and the kind of target site and sickness. Nanotechnology has been acquainted with take care of the issues related with improving solvency and bioavailability.[4]

TYPE OF NANOFORMULATION

-Polymeric Nanopartical
-Lipid-based Nanoparticles
-Nanoemulsions
-Metallic Nanoparticles
-Dendrimers
-Liposomes & Niosomes

Polymeric Nanopartical

Polymeric nanoparticles are colloidal carrier systems made from natural or synthetic polymers, with particle sizes typically ranging from 10 to 1000 nm. They can be designed as nanospheres (matrix type) or nanocapsules (reservoir type), where drugs or bioactive agents are either entrapped, adsorbed, or covalently bound to the polymer matrix. . Nanoparticles intervened focusing on assumes a huge job in repressing the aggravation, angiogenesis and tumor progression.[5]

APPLICATION

-Drug Delivery Systems
-Cancer Therapy
-Gene and Protein Delivery
-Diagnostics and Imaging
-Vaccine Delivery
- Antimicrobial therapy

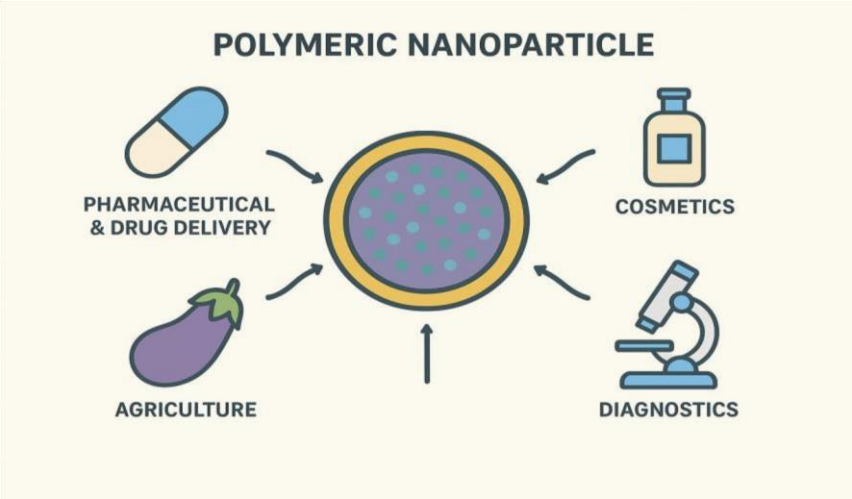

FIG NO 3. POLYMERIC NANOPARTICLE

-Lipid-based Nanoparticles

Lipid-based nanoparticles are nanocarrier systems (size 10–1000 nm) made from physiological or synthetic lipids that encapsulate or incorporate drugs. They are biocompatible, biodegradable, and less toxic, making them widely used in drug delivery[6]

-Improve bioavailability of poorly soluble drug

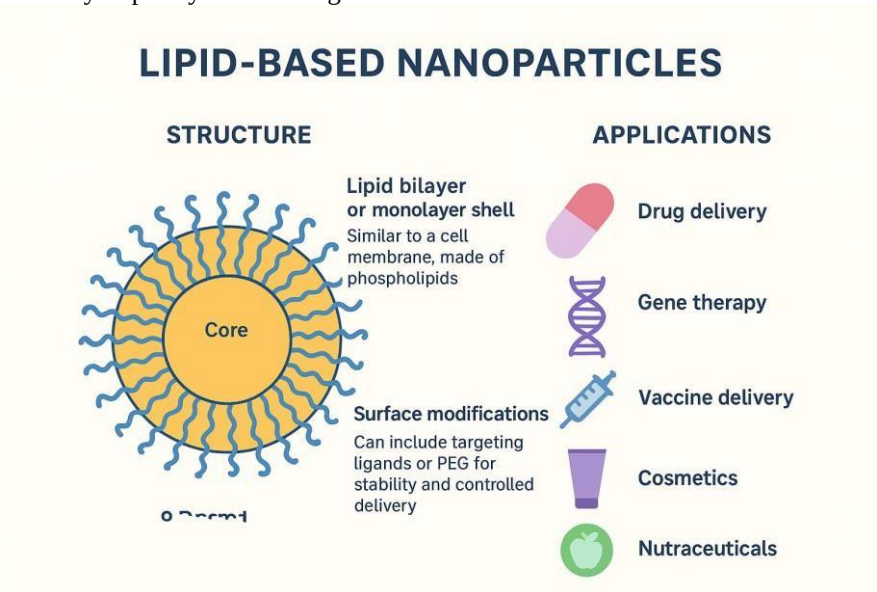

FIG NO 4. LIPID BASED NANOPARTICLES

-Nanoemulsions

Nanoemulsions are thermodynamically or kinetically stable colloidal dispersions of two immiscible liquids (oil and water) stabilized by surfactants, with droplet sizes typically in the range of 20–200 nm

Nanoemulsion-based conveyance frameworks comprise of a colloidal scattering of oil and water stages, in which mean bead breadths ranges from around 50 to 500 nm in pharmaceutical applications. Nanoemulsions may exist as an oil-in-water (o/w) or water-inoil (w/o) form[7] Emulsions are generally utilized in restorative creams, salves, hairsprays and sunscreens, pharmaceutical conveyance frameworks for lipophilic medications, paints, dry-cleaning definitions, agrochemical items, and the oil industry[8]

-Oil-in-water (O/W) – oil droplets dispersed in water

-Water-in-oil (W/O) – water droplets dispersed in oil

Application

1)Oral Delivery : The utilization of nanoemulsions as oral medication conveyance frameworks expands the general bioavailability of medications, including micronization/nanonization, strong scatterings, and complexation with cyclodextrins, amorphization, and usage of particulate conveyance frameworks that are dispersible in fluid situations.

2)Parenteral Delivery : For drugs with low bioavailability and limited remedial file, the

parenteral course is viewed as one of the most well-known and compelling courses.

3) Intranasal Delivery : Intranasal tranquilize conveyance is another dependable course for the organization of specific sorts of medications which is utilized in the treatment/the board of conditions, for example, hormone substitution treatment (estradiol), osteoporosis (raloxifene), schizophrenia (olanzapine), smoking discontinuance (nicotine), enuresis (desmopressin), endometriosis (nafarelin), and movement affliction (metoclopramide).

4)Nanoemulsions for Vaccine Delivery : : Most of the examination on nanoemulsions for antibody conveyance focuses on intranasal mucosal strategies

5)Nanoemulsions for Gene Delivery : The nearness of cationic surfactants permits the complexation with contrarily charged DNA through electrostatic communications, which brings about DNA compaction and nanocomplex arrangement. The idea of quality conveyance is very clear and it includes the inclusion of qualities into physical cells of patients for amendment of an inalienable hereditary deformity or making of another cell function.

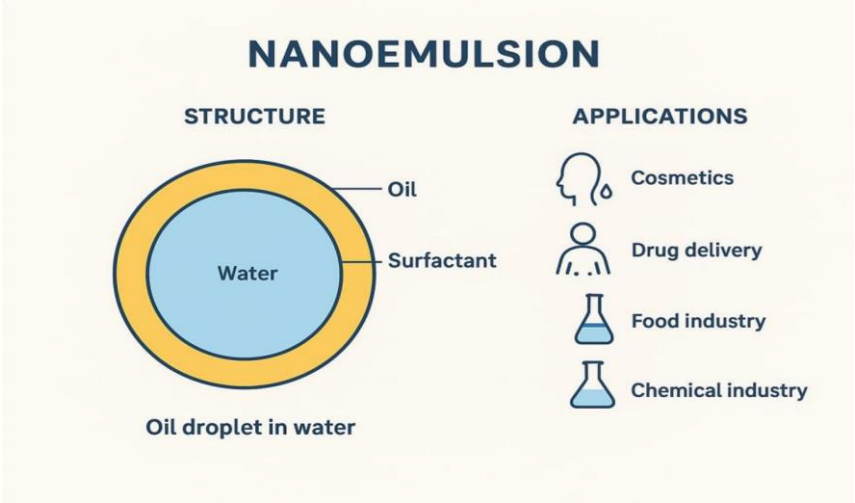

FIG NO 5 . NANOEMULSION

-Metallic Nanoparticles

Metallic nanoparticles are nanosized particles (1–100 nm) made from metals like gold (Au), silverNanoemulsions for Gene DeliveryNanoemulsions for Gene Delivery (Ag), platinum (Pt), iron (Fe), zinc oxide (ZnO), titanium dioxide (TiO_2), etc.. They exhibit unique optical, magnetic, electrical, and catalytic properties due to their high surface area-to-volume ratio and quantum effects.They can be synthesized by chemical, physical, or biological methods and are widely used in medicine, electronics, and environmental fields.

Application

-Medical and Pharmaceutical Applications
-Biosensing and Diagnostics
-Environmental Applications

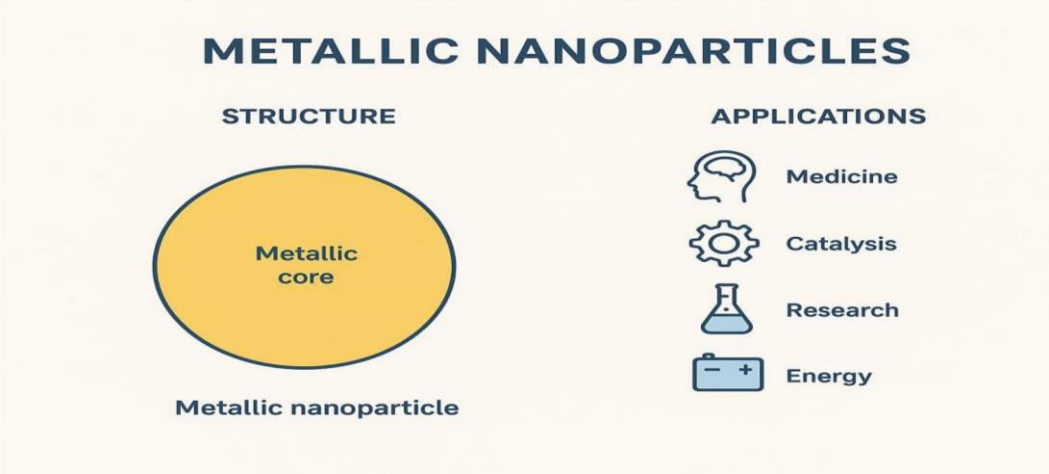

FIG NO 6. METALLIC NANOPARTICLES

- Dendrimers

Dendrimers are highly branched, tree-like synthetic macromolecules with a welldefined, symmetrical structure.
-Nanosized, highly branched polymeric structures with multiple functional groups.
-Allow precise drug loading and surface modification.
-Suitable for targeted delivery and gene therapy.
-Dendrimer-based bearers offer the chance to improve the oral bioavailability of risky medications accordingly, upgrade the bioavailability of medications that are inadequately solvent or potentially substrates for efflux transporters

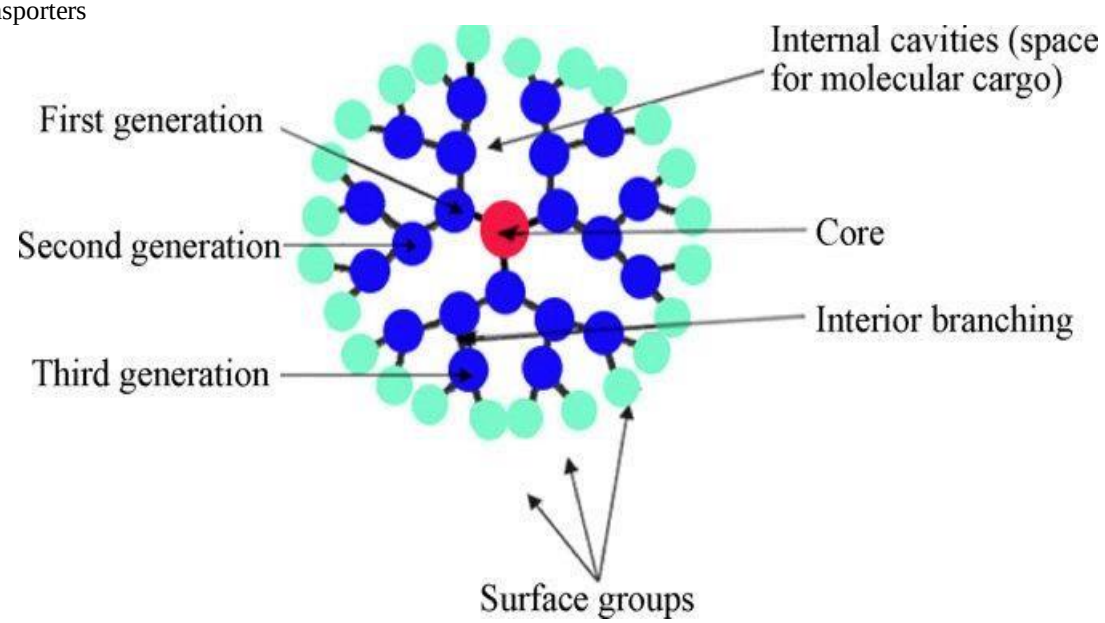

FIG NO 7. DENDRIMERS

-Liposomes & Niosomes

Liposomes :

Liposomes are spherical vesicles composed of one or more phospholipid bilayers surrounding an aqueous core. They are biocompatible and can carry both hydrophilic (in core) and lipophilic (in bilayer) drugs.

Liposomes are the little counterfeit vesicles of round shape that can be acquired from cholesterol and normal nontoxic phospholipids. Liposome properties vary with lipid structure, surface charge, size, and the technique for readiness.

Applications & Uses

a)Pharmaceutical Applications

1.Fundamental Liposomal Drugs: Liposome's can fill in as a superb medication conveyance vehicle to the mononuclear phagocytic framework cells (MPS), generally fixed Kuppfer cells present in the liver and spleen, which have indicated upgraded aggregation in destinations of injury, for example, tumors, diseases and inflammation.[9]

2.Topical Liposomal Drugs: Skin treatment utilizations of liposomes depend on the closeness between the lipid vesicles bilayer structure and regular membranes[10] In Schmid's work, layer corneum liposome's are been utilized in the treatment of atopic dry skin so as to reestablish the obstruction work and to vehicle a functioning substance[11]

3.Restorative Applications: Liposome's can be used in beauty care products since they are very much hydrated and can lessen the dryness of the skin which is an essential driver for maturing. It likewise flexibly renew lipids and significantly linolenic corrosive to the skin.

4.Food Applications: Food researchers have started to use liposomes for controlled conveyance of useful segments, for example, proteins, compounds, nutrients, cancer prevention agents, and flavours and applications, for example, dairy items arrangement, adjustment of food parts against debasement, and conveyance and upgraded effectiveness of antimicrobial pepties[12]

5.Liposome in anticancer treatment: Diverse liposome definitions of various anticancer operators were demonstrated to be less harmful than the free medication accessible in market. [13-14] An Anthracyclines sedate stops the development of separating cells by the intercalating into the DNA and, in this manner, slaughters quickly partitioning cells. The most utilized and considered is Adriamycin (commercial name for doxorubicin HCl)15.

Niosomes:
Niosomes are vesicular systems similar to liposomes but made of nonionic surfactants instead of phospholipids. They are more stable, costeffective, and easier to store than liposomes.

__[Hydrophilic drug in core]
OO <— Bilayer made of non-ionic surfactants + cholesterol

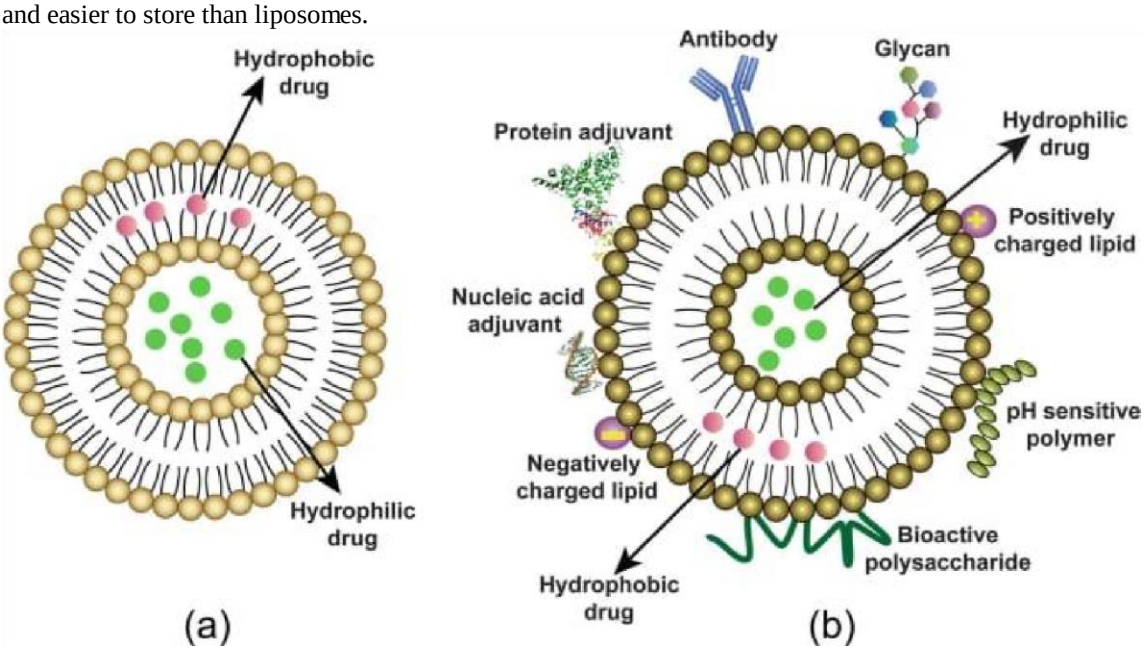

FIG NO 8. Liposomes & Niosomes

ADVANTAGE & DISADVANTAGE

ADVANTAGE	DISADVANTAGE
Improved Drug Solubility: Increases solubility of poorly water-soluble drugs.	High Production Cost: Preparation and equipment are expensive.
Enhanced Bioavailability: Improves absorption and effectiveness of drugs.	Complex Manufacturing Process: Requires advanced technology and expertise.
Targeted Drug Delivery: Delivers drugs directly to the diseased site, reducing side effects.	Toxicity Issues: Some nanoparticles may show toxicity or cause immune reactions.
Controlled/Sustained Release: Maintains drug concentration for a longer period.	Stability Problems: Nanoparticles may aggregate or degrade during storage.
Reduced Dose Frequency: Improves patient compliance by reducing how often doses are needed.	Regulatory Challenges: Difficult to get approval due to lack of standardized guidelines.
6. Protection of Drug: Protects drugs from degradation (chemical or enzymatic).	Environmental Concerns: Disposal of nanomaterials may affect the environment.

APPLICATION
1)Drug Delivery :
-Nanoformulations are extensively used to improve drug delivery by enhancing solubility, stability, and bioavailability of drugs.
Targeted drug delivery: Nanocarriers can deliver drugs specifically to diseased tissues (e.g., tumors) while sparing healthy cells.
-Controlled release: Nanoparticles can release drugs in a sustained or stimuliresponsive manner (pH, temperature, enzymes).
-Improved absorption: Nanoformulations can enhance the oral bioavailability of poorly soluble drugs.
Example: Paclitaxel-loaded nanoparticles for cancer therapy.
2)Cancer Therapy :
-Tumor targeting: Nanoparticles exploit the Enhanced Permeation and Retention (EPR) effect to accumulate in tumors.
-Combination therapy: Multiple drugs can be loaded in a single nanocarrier for synergistic effects. -

Reduced toxicity: Targeted delivery reduces adverse effects on healthy tissues

3)Gene Therapy :

-Nanoparticles protect DNA, RNA, and siRNA from degradation.

-Facilitate cellular uptake and precise genetic modulation.

-Example: Lipid nanoparticles in mRNA vaccines

4)Vaccine Delivery :

-Nanoformulations act as adjuvants and improve antigen stability.

-Enable needle-free delivery via mucosal routes.

-Example: COVID-19 mRNA vaccines.

5)Topical and Transdermal Delivery :

-Enhance skin penetration and retention of drugs.

-Reduce local irritation and improve therapeutic efficacy.

-Example: Nanoemulsions for anti-inflammatory topical therapy

METHOD OF PREPARATION

1)Top down method : These methods involve the reduction of bulk drug material to nanoscale dimensions using mechanical or physical forces.

a)High pressure Homoginazation : This technique involves forcing a coarse suspension through a narrow gap under high pressure, leading to particle size reduction due to shear forces and cavitation. It is widely used for the production of solid lipid nanoparticles and nanocrystals. At the point when the size is decreased through high weight, it becomes unilamellar liposome after which microfluidizer was utilized to constrain the feed material under high tension through a thin orifice. The utilization of microfluidizer helps in the expulsion of bilayers from the liposome structure in which layer partition instrument was pertinent just to liposome's with emphatically charged phospholipids and size more prominent than 70µm.[15-16]

b)Milling Techniques (Ball Milling/Wet Milling): Mechanical attrition using milling media can reduce the particle size to the nanometer range. Although effective, challenges such as contamination from milling media and broad size distribution are common[17].

c)Ultrasonication: High-frequency ultrasound waves generate cavitation forces that break down drug particles into nanosize. It is often applied in the preparation of liposomes and polymeric nanoparticles. The nanoemulsion readiness by ultrasonic homogenization was accounted for in different reports for bead formation.[

2)Bottom–Up Approaches

These methods rely on the self-assembly or precipitation of drug molecules from solution, making them suitable for poorly water-soluble drug . It is commonly a traditional precipitation procedure in pharmaceutical science and technology[18-19]

a)Nanoprecipitation (Solvent Displacement)

The drug is dissolved in an organic solvent and added to an aqueous phase, leading to rapid diffusion and spontaneous nanoparticle formation[20-21]. This is one of the most widely employed methods for polarmarcic nanopartical Pharmaceutical suspension is a coarse scattering wherein inward stage for example insoluble strong particles is scattered consistently all through the outer stage with help of single or blend of suspending age

b)Emulsification–Solvent Evaporation:

The drug and polymer are dissolved in a volatile organic solvent and emulsified in an aqueous phase. Evaporation of the solvent results in nanoparticle formation

c)Solvent Diffusion Method:

Here, a partially water-miscible solvent containing the drug diffuses into the aqueous phase, causing controlled precipitation of nanoparticles

d)Ionic Gelation/Polyelectrolyte Complexation:

Nanoparticles are formed through electrostatic interactions between oppositely charged polymers (e.g., chitosan and sodium tripolyphosphate)

e)Supercritical Fluid Technique:

Supercritical carbon dioxide acts as a solvent or antisolvent for the drug, leading to nanoparticle precipitation with narrow size distribution

EVALUATION PARAMETERS

1) Particle Size and Size Distribution

Particle size is a critical determinant of biodistribution, drug release, and stability of nanoformulations. Dynamic light scattering (DLS), transmission electron microscopy (TEM), and scanning electron microscopy (SEM) are commonly employed techniques. Nanoparticles with sizes <200 nm show enhanced absorption and cellular uptake[22-23]

2)Polydispersity Index (PDI)

PDI reflects the uniformity of particle size distribution. A PDI <0.3 indicates monodispersity and stability, while higher values suggest aggregation or heterogeneity.

3)Zeta Potential

Zeta potential measures surface charge, which is crucial for colloidal stability. Particles with high positive or negative zeta potential (±30 mV or more) are less prone to aggregation, thereby improving shelf-life[25].

4)Morphiological and surface characteristic

Shape and surface smoothness of nanoparticles influence drug release and interaction with biological systems. Techniques like TEM, SEM, and atomic force microscopy (AFM) are widely used for morphological analysis

5)Drug Loading and Entrapment Efficiency

Drug Loading (DL%): Represents the amount of drug incorporated into nanoparticles relative to total carrier weight.

Entrapment Efficiency (EE%): Indicates the proportion of drug successfully entrapped within the carrier system.

High values of DL and EE improve therapeutic effectiveness and reduce dosage frequenc

6)In-vitro Drug Release

Drug release kinetics are studied using diffusion-based methods (e.g., dialysis bag, Franz diffusion cell). This parameter helps classify formulations as immediate, sustained, or controlled release system

7)Stability Studies

Stability testing under real-time and accelerated conditions evaluates changes in particle size, zeta potential, drug content, and release profile. It ensures product quality throughout shelf life.

8)Surface Area and Porosity

Analyzed by Brunauer–Emmett–Teller (BET) analysis, these parameters affect drug adsorption, loading, and release.

9)Crystallinity and Physical State

X-ray diffraction (XRD) and differential scanning calorimetry (DSC) are used to assess crystallinity. Drugs in the amorphous state often show higher solubility compared to crystalline forms.

10)In-vitro Cytotoxicity and Biocompatibility

Cytotoxicity studies such as MTT assay, hemolysis test, and cell viability assays evaluate the safety of nanoformulations. Biocompatibility ensures non-toxic interaction with cells and tissues.

11)In-vivo Pharmacokinetics and Pharmacodynamics

Animal studies provide data on absorption, distribution, metabolism, excretion
(ADME), and therapeutic efficacy. These studies validate in-vitro findings and confirm targeting efficiency.

CONCLUSION:

Nanoformulations represent a significant advancement in drug delivery, offering solutions to many challenges associated with conventional therapies. However, extensive research is still required to address stability, safety, and large-scale production challenges before their full clinical potential can be realized.

An effective nanoformulation is one which offers business appropriateness to pharmaceutical enterprises for enormous scope creation. The principle point of this survey is to give data about the diverse amalgamation strategies that are accessible for setting up each kind of nanodetails and their applications. The nanoformulations have extraordinary possibilities, having the option to change over inadequately dissolvable, ineffectively retained and labile naturally dynamic substance into promising deliverable medications. The field of nano-definition is currently changing into a significant piece of pharmaceutical industry and which requires consideration on crucial research to create proficient nano-detailing for tranquilize conveyance application

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