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Review Article

Recent Progress in Niosomes for Enhanced Bioavailability and Site-Specific Drug Delivery

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ABSTRACT

Targeted drug delivery, was first developed by Paul Ehrlich in 1909, with the development of vesicular carriers such as niosomes. Niosomes are microscopic, and bilayered vesicles which are composed of non-ionic surfactants and cholesterol, and stabilized with additives like dicetyl phosphate. Their amphiphilic nature allows them to encapsulate both hydrophilic and hydrophobic molecules, Compared to liposomes, niosomes are more chemically stable, has lower production costs, easy to store, and reduces toxicity, which makes them as an alternatives for pharmaceutical and cosmetic applications. Niosomes has a wide range of applications through multiple routes of administration like oral, parenteral, ocular, topical, and transdermal which provides them a controlled, sustained, and site-specific drug release. Niosomal gels, elastic vesicles, and proniosomes have challenges like leakage and instability of the dosage form, which enhances the dermal penetration, drug retention, and therapeutic efficacy which requires a long-term therapy, it improves the bioavailability and reduces systemic toxicity. Their nanoscale size and biocompatibility enables the potential use in central nervous system by targeting the drug transport across the blood–brain barrier. Recent research highlights the potential use of niosomes as they are capable of integrating the targeting ligands, imaging agents, or responsive polymers to achieve combined diagnostic and therapeutic functions. As these challenges includes large-scale production, regulatory approval, and long-term safety. Overall, niosomes have a great advancement in novel drug delivery, along with combining stability, cost-effectiveness, and adaptability. They enhance solubility, permeability, and therapeutic index while minimizing side effects which makes them one of the Nano carrier systems for future applications in pharmaceuticals and also in personalized medicine.

INTRODUCTION

Paul Ehrlich in 1909 initiated and started the development of targeted drug delivery. He

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envisaged a mechanism for the delivery of drugs that would directly target diseased cell. Drug targeting can be characterized as the ability to direct a therapeutic agent directly to the intended site of action with little or no non-target tissue involvement. In niosome, amphiphilic vesicles are from non-ionic surfactant like Span-60 i.e. normally stabilized by adding cholesterol and a small amount of anionic surfactant or dicetyl phosphate. The first non-ionic surfactant vesicles were prepared and marketed by L'Oréal's company which is used cosmetic applications¹. Niosomes such as targeting, ophthalmic, topical, parental, etc. can be used for various types of drug delivery.

Niosomes are microscopic lamellar structures and smaller in size with a size range between 10 or 20nm to 1000 nm. Their small size can easily pass through any transdermal routes of administration. The niosome is made up of surfactants that are non-immunogenic, biodegradable and biocompatible and they are better than liposomes and their higher surfactant chemical stability than phospholipids which are easily hydrolysed by the ester bond and it is cost-effective.² Niosome contains different charge on their surface due to the different charge like (+) and (-), it shows flocculation or aggregation, which reduces ionic surfactant that is added for maintaining same charge in formulation. Span-60 is non-ionic surfactant which is used in the formulation of niosome.³

Niosome does not require any special condition for preparation and storage conditions like liposome. For formulation of niosome in its non-ionic surfactant it shows more stability than phospholipid and is used in preparation of liposome. In liposomes, phospholipid contains ester bond and due to this bond, phospholipid undergoes hydrolysis. Niosome shows the controlled release

of drug in blood circulation at pre-determined time and at pre-determined rate. Some niosomes are water soluble carrier particles which are coated with surfactant or in dry form of niosome which are also called as pro-niosome. The pro-niosome reduces the many problems of such as its physical stability.⁴ Pro-niosome are also another drug delivery formulation, which shows good transdermal penetration property because it contains surfactant, which acts as a penetration enhancer and it is also non-toxic, biodegradable and they can be entrapped both hydrophilic and lipophilic drug in it.

The niosomal formulation decreases the systemic non-selective toxicity of anti-cancer drug. Cholesterol is the important structure of niosome which gives rigidity to vesicle but when cholesterol is added in more quantity in vesicle it not only affects the fluidity but also penetration and permeability of drug.⁵ Niosomal formulation is administered by several routes such as transdermal, parenteral, oral, ocular and subcutaneous route. In targeted drug delivery several carriers are used such as immunoglobulin, plasma protein, microsphere, synthetic polymers, and sometimes erythrocytes.⁶

Targeted drug delivery is a concept which aims to concentrate a drug in the tissues by lowering the relative concentration. Which results in the localisation of the drug at the desired location. As a result, the medication has no effect on the underlying tissues. Synthetic polymers, liposomes, microspheres, erythrocytes, and niosomes have been targeted using various carriers.⁷ Niosomes are vesicular nano carriers which have amphiphilic molecules in a lamellar (bilayer) structure surrounded by an aqueous compartment which contains both hydrophobic (tails) and hydrophilic (heads) that are self-assembling, which gets aggregated into a variety of shapes like



micelles or into a planar lamellar bilayer. the bilayer structure is oriented away from the aqueous solvent, while the hydrophilic heads remain in contact with it.⁸The composition of the vesicles, size, tapped volume, surface charge, and concentration can be modified. Various forces act within the molecules, including repulsive forces arising from electrostatic interactions between charged groups of surfactant molecules.⁹

In the past years, research has been focused on the elaboration of various drug delivery systems, which aims to overcome the limitations of conventional dosage forms and to ensure an improved bioavailability, reduced side effects, controlled drug release, and targeted delivery. The elaboration of different types of vesicular carriers such as niosomes, transferosomes, ethosomes, pharmacosomes, etc., which retain the characteristic lamellar structure, but differ in the type of structural components. Over the years, niosomes have been investigated as a promising drug delivery platform for various routes of administration oral, parenteral, dermal/transdermal, ocular, and pulmonary.¹⁰

Niosomes are novel drug delivery system, which entrapped the hydrophilic drug into core cavity and hydrophobic drug into the non-polar region present within the bilayer, hence both these hydrophilic and hydrophobic drugs can be incorporated into niosome.¹¹The main reason of developing a niosomal system is chemical stability, biodegradability, biocompatibility, low production cost, easy storage, easy handling, and low toxicity. Niosomes can be administrated through various routes such as oral route, parenteral route, topical route, ocular route etc.

For many decades, medication of an acute disorder or a chronic illness has been developed by delivering the drugs to the patients through various pharmaceutical dosage forms like tablets,

capsules, pills, creams, ointments, liquids, aerosols, parenteral and suppositories as carriers.

¹²Niosomes are one of the best carriers. There are various techniques to obtain a controlled release system, of niosomes.¹³The multilamellar or unilamellar structure of niosomes are formed by mixing non-ionic surfactant, cholesterol, and diethyl ether along with subsequent hydration in aqueous media.

Niosomes are nanometric size or multilamellar or tiny lamellar vesicle which is formed by the hydration of synthetic surfactant (non-ionic) with or without the addition of sterols (cholesterol) or other lipids. They are more stable than liposome due to their structural components¹⁴. They are less toxic and more stable than liposome because as it contains non-ionic surfactant. The particle size of niosome ranges in between 20 nm -100 nm. They are biodegradable, non-immunogenic and biocompatible surfactants with 10nm -100nm size range.

The vesicles is formed in amphiphilic which is a non-ionic surfactant that is normally stabilized by adding cholesterol and a little quantity of anionic surfactant such as dicetyl phosphate, it helps in vesicle stabilization. Niosomes have hydrophilic and hydrophobic moieties, which allows them to accept medicinal molecules with a variety of solubilities¹⁵. Niosomes are used for a variety of drug delivery methods, which includes targeted, ocular, topical, parenteral. Niosomes have drug carrier, which minimizes the medication side effects and improve therapeutic efficacy.¹⁶

Niosomes are a new and novel drug delivery system (NDDS) which delivers the medication at a determined rate to treat an illness which improves absorption and distributes the active substance to the target location. Niosomes can readily pass through all routes of action via the skin¹⁷. The niosomes undergoes less metabolism



and removal by the reticular endothelial system due to its Nano size. Niosomes are non-ionic in nature, have low toxicity, and improves drug therapeutic efficiency by targeting certain cells.

Table. 1 Advantages and Disadvantages of Niosomes

Advantages of Niosomes	Disadvantages of Niosomes
<ul style="list-style-type: none"> ▪ Inexpensive ▪ Improves therapeutic targeted performance of drug by delaying the clearance of drug from the blood circulation. ▪ Less toxic ▪ The structure of niosome show all types of nature like hydrophilic, lipophilic and amphiphilic. ▪ Surfactant are biodegradable, biocompatible, non-immunogenic and non-allergic. ▪ Niosomes can easily penetrates into skin and enhances skin penetration of drug. ▪ Handling and storage of surfactant does not require any special condition so it reduces the cost of the preparation. <ul style="list-style-type: none"> ▪ Niosomes are osmotically stable and active. ▪ Niosomes shows slow or controlled release drug delivery. <ul style="list-style-type: none"> ▪ They increase drug permeation through the body. ▪ Niosomes helps in improving the stability of loaded drug. 	<ul style="list-style-type: none"> ▪ Extrusion and sonication are used for preparing multilamellar vesicles which takes time and may require specialized equipment for processing. ▪ Due to fusion, aggregation, leakage of entrapped medicines, and hydrolysis of encapsulated medicines, the shelf life of niosomes aqueous suspensions is restricted. <ul style="list-style-type: none"> ▪ Cost of drug delivery is high. ▪ Phospholipids can be oxidized and hydrolysed.

18 CLASSIFICATION/ TYPES OF NIOSOMES

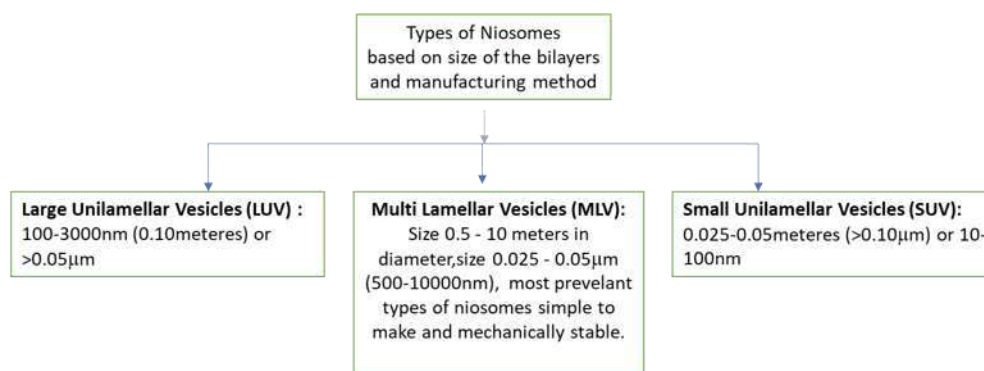


Figure.1 Classification of Niosomes

1. Multilamellar vesicles (MLV)

It consists of several bilayers surrounding the aqueous lipid compartment separately. The size of these vesicles is 0.5-10 µm diameter. These vesicles are the most widely used niosomes. And are highly suited as a drug carrier for lipophilic compounds. They are easy to prepare and they are more stable for long period of time. These vesicles

are more suitable for lipid drug compound. This types of niosomes are mainly prepared by thin film hydration method or hand shaking method. (Size=>0.05 µm)

2. Large unilamellar vesicles (LUV)

Niosomes of this type have a high aqueous or lipid compartment ratio, so that the larger volume of

bio-active materials can be entrapped with very economical use of membrane lipids. These can be prepared by using reverse phase evaporation or the detergent solubilisation process. (Size=>0.10 μm).

The small uni-lamellar vesicles are prepared from multilamellar vesicles by sonication method, French press extrusion electrostatic stabilization is the inclusion of diacetyl phosphate in 5,6 - carboxyfluorescein loaded Span 60 based niosomes. (Size=0.025-0.05 μm)

3. Small unilamellar vesicles (SUV)

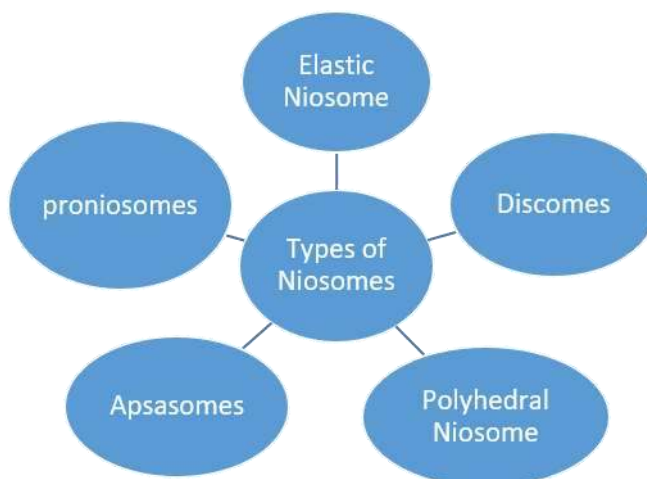


Figure. 2 Types of Niosomes

¹⁹PROPERTIES OF NIOSOMES

1. Niosomes can entrap solutes as like a similar to liposomes
2. Niosomes are bilobular supporter active and stable
3. Niosomes retain an infra- structure conforming of hydrophobic and
4. hydrophilic substantially together and can accommodate the medicine with a wide range of solubility.
5. Niosomes have inflexibility in their structural characteristics (composition, fluidity and size)

and can be designed according to the demanded situation.

6. Niosomes may ameliorate the performance of the medicine notes
7. Better vacuity to the particular point of administration by guarding the medicine from natural terrain.
8. Niosomes surfactants are biocompatible and non-immunogenic.

^{20,21}Comparison between Niosomes and Liposomes

Table.2 Comparison between Niosomes and Liposomes

Niosomes	Liposomes
It uses Non-ionic surfactant-based vesicles	It uses Phospholipid-based vesicles
It is formed from non-ionic surfactants and cholesterol	It is Composed of natural or synthetic phospholipids and cholesterol
They are more chemically more stable	They are less stable

Relatively inexpensive (surfactants are cheaper)	Expensive (high-purity phospholipids are costly)
Biocompatible and less biodegradable compared to liposomes	Highly biodegradable and biocompatible
Easier to prepare, requires simpler conditions	Requires more sophisticated techniques for preparation
Can encapsulate both hydrophilic and lipophilic drugs	Can encapsulate both hydrophilic and lipophilic drugs
Low toxic due to non-ionic surfactants	They have very low toxicity as the natural phospholipids resemble cell membranes
Longer shelf life due to better stability	Shorter shelf life due to phospholipid degradation
Widely used in drug delivery, cosmetics, and vaccines	Used in drug delivery, gene therapy, and as carriers in cancer treatment

Structure of Niosomes

²²The niosome are circular bilayer structure of non-ionic surfactant like span-60 surfactant which has the ability to form micelle. When surfactant concentration goes above the critical micelle concentration (CMC) then it forms micelles in formation, but non-ionic surfactant has ability to form circular bilayer structure instead of micelles. The cholesterol is also added in formulation to give rigidity to vesicle and ionic surfactant reduces aggregation. The structure of niosome can be uni-

lamellar or multi-lamellar depending on which method used for preparation of niosome.

²³There are all types of drugs can be incorporate in structure of niosome such as hydrophilic, lipophilic and amphiphilic drugs. Because of their peculiar structure as vesicular systems, niosomes can encapsulate both hydrophilic and lipophilic substances. Lipophilic substances are entrapped by partitioning into the lipophilic domain of the bilayers, whereas hydrophilic substances are adsorbed on the bilayer surfaces.

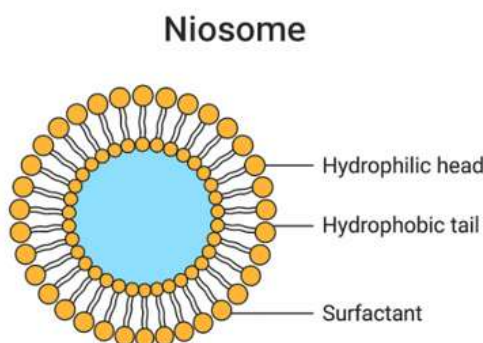


Figure.3 Structure of Niosome

CHARACTERIZATION OF NIOSOMES

1. Bilayer Rigidity and Homogeneity: Niosomes are determined by the bilayer's rigidity. In homogeneity, dispersion can occur within niosome and can be defined by: PNMR, Differential Calorimetry Scanning (DSC) and Fourier Red

Spectroscopy Transform-Infra (FT-IR) techniques.²⁴

2. Size and Shape: Different methods are used to calculate the mean diameter, such as the process of laser light scattering, as well as electron microscopy, molecular sieve chromatography,

photon correlation microscopy, optical microscopy.

3. Stability Study: Niosomal formulations are subject to stability studies by processing for a duration of three months at 4 ° C, 25 ° C and 37 ° C in a thermostatic oven. After a month, the drug quality of all the formulations is tested by entrapping efficiency the parameter of output.

4. Scanning Electron Microscopy: ²⁵In a scanning electron microscope (SEM) (JSM 6100 JEOL, Tokyo, Japan) the niosomes were detected. The niosomes were mounted directly onto the SEM sample stub using double-sided sticking tape and coated under a reduced pressure of 0.001 mmHg with 200 nm thick gold film. At sufficient magnification, photographs were taken.

5. Vesicle Charge: The surface charge of the vesicle plays a significant role in the actions of in vivo and in vitro niosomes. Charged niosomes are more stable than uncharged vesicles against aggregation and fusion. To obtain an approx. surface potential, micro electrophoresis can be used to calculate the zeta potential of individual niosomes. The use of pH-sensitive fluorophores is an alternative approach. More recently, for calculating the zeta potential of niosomes, dynamic light scattering was used.

6. Niosomal Drug Loading and Encapsulation Efficiency: ²⁶The niosomal aqueous suspension was ultracentrifuged, supernatant was removed and sediment is washed twice with distilled water to remove the adsorbent material to assess drug loading and encapsulation capacity.

The entrapment efficiency (EE) was then calculated using formula:

▪ $\text{Entrapment efficiency} = \frac{\text{amount of drug in niosomes}}{\text{amount of drug}} \times 100$

7. In-vitro Release: ²⁷In-vitro release rate study carried out by the use of

1. Dialysis Tubing: A dialysis bag is washed with distilled water. The prepared vesicle suspension is piped into a bag consisting of the dialysis of the tubing and sealed after, then the bag containing the vesicles is put in a 250 ml beaker with a steady shaking at 25 ° C in 200 ml of buffer solution. The buffer is an analysis of the drug content of a suitable system of research at different time intervals.²⁸

2. Reverse dialysis: ²⁹A number of small dialysis is put in proniosomes as containing 1ml of the dissolution medium. The pro-niosomes are then transferred to the process of dissolution. Direct pro-niosome dilution is possible.

Limitation: It is not possible to quantify the rapid release using this method.

3. Franz diffusion cell: ³⁰Using Franz diffusion cell, the study of in vitro diffusion can be performed. Pro-niosomes are placed in a Franz diffusion cell's donor chamber filled with cellophane membrane. The pro-niosomes are then dialyzed at room temperature against an acceptable dissolution medium; and then the samples are removed from the medium at suitable time intervals and tested for drug content using specific methods such as U.V spectroscopy, HPLC, etc.

³¹**COMPOSITION OF NIOSOMES**

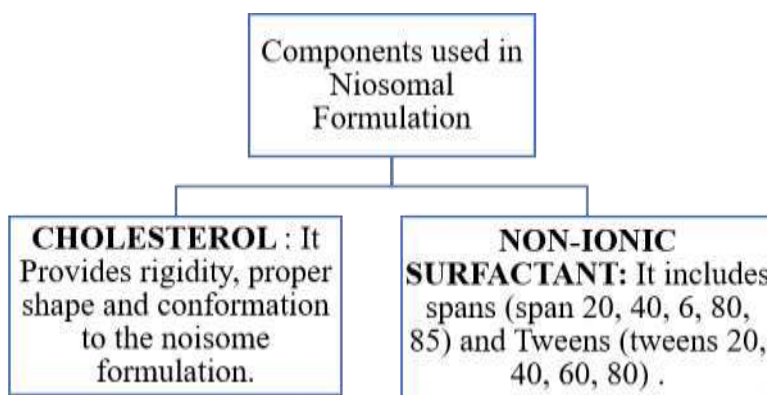


Figure. 4 Composition of Niosome

³²Formulation/ Approaches to Niosomes

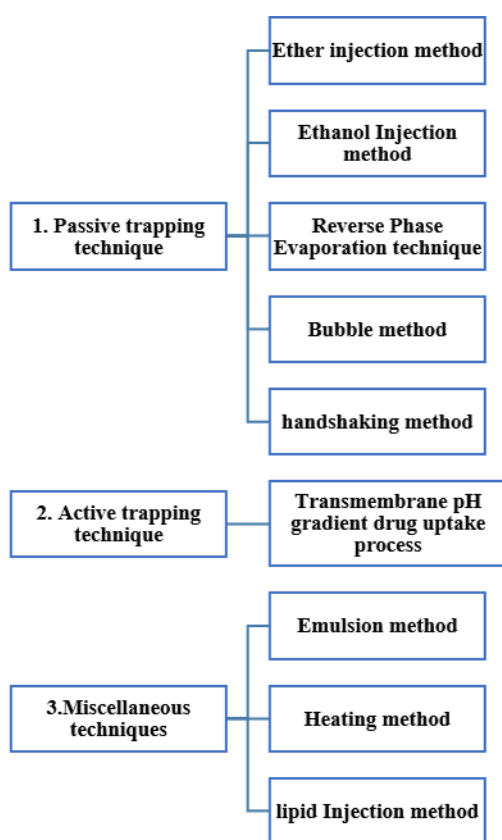


Figure.5 Formulation approaches to Niosomes

Evaluation of Niosomes

1. Entrapment Efficiency (EE%): ³³Free drug present in the dispersion is removed by dialysis, centrifugation, or gel filtration techniques. The vesicles are then disrupted using solvents such as 50% n-propanol or surfactants like 0.1% Triton X-100, and the

entrapped drug is quantified by a suitable analytical method.

$$EE (\%) = \frac{\text{Entrapped drug}}{\text{Total drug added}} \times 100$$

2. Confirmation of Bilayer Formation: The assembly of surfactants into bilayer vesicles can be confirmed by the appearance of a Maltese cross (X-cross) pattern when observed under polarized light microscopy.³⁴

3. Vesicle Size and Morphology: Niosomes are usually spherical in shape, and their mean vesicle diameter can be determined by techniques such as laser light scattering, photon correlation spectroscopy, molecular sieve chromatography, ultracentrifugation, and electron microscopy (TEM/SEM). Freeze-fracture electron microscopy and optical microscopy are also useful methods.³⁵

4. Number of Lamellae: The number of bilayers within vesicles can be assessed using nuclear magnetic resonance (NMR) spectroscopy, small-angle X-ray scattering (SAXS), and electron microscopy.

5. Membrane Rigidity: ³⁶Bilayer rigidity is generally evaluated by studying the movement of fluorescent probes across the vesicle membrane as a function of temperature.

6. In-Vitro Release Studies: The release profile of drug from niosomes can be studied using the dialysis bag technique. In this method, the niosomal suspension is filled into a dialysis sac and immersed in a buffer medium (200 mL) maintained at 25–37 °C with continuous shaking. At pre-determined intervals, samples are withdrawn and analyzed for drug content³⁷.

7. Microscopic Evaluation:³⁸ Transmission electron microscopy (TEM) is widely used for studying vesicle size, shape, and surface morphology, and to confirm the spherical nature of the vesicles.

^{39,40} Factors affecting Niosomal Formulation

1. Nature of encapsulated drug
2. Nature and type of surfactant
3. Cholesterol content and charge
4. Resistance to osmotic stress
5. Temperature of hydration
6. Bilayer formation
7. Number of lamellae
8. membrane composition and Rigidity

Recent Advances in Transdermal Niosomal Drug Delivery

Research on niosomes for transdermal drug delivery has expanded in recent years, with emphasis on optimizing preparation methods, exploring novel excipients, and improving final formulations. One important development is the introduction of elastic vesicles, in which edge activators (e.g., ethanol) impart flexibility to the bilayer.⁴¹ This increased deformability allows the

vesicles to pass more efficiently into deeper skin layers, enhancing drug penetration.

⁴²A drawback of conventional niosomes is their liquid state, which may lead to leakage after topical application. This issue can be resolved by formulating niosomal gels, where gelling agents are added to the dispersion. Such gels provide better retention on the skin and maintain sustained drug release over time. The evolution of niosomes has also led to the creation of proniosomes, which are dry, free-flowing systems that must be hydrated before use to generate niosomes.⁴³ When applied under occlusion, hydration from the skin converts proniosomes into vesicles in situ. This approach minimizes issues such as fusion, leakage, and instability, making proniosomes a more stable alternative for dermal delivery.

⁴⁴Studies over the past decade have reported encouraging outcomes with NSAIDs delivered via niosomal systems. Oral administration of these drugs often results in gastrointestinal irritation and extensive first-pass metabolism, reducing systemic bioavailability to nearly half. Transdermal formulations bypass these drawbacks and are especially useful for long-term therapy in rheumatic conditions, provided the drug can sufficiently penetrate the skin.⁴⁵ For example, it evaluates the role of penetration enhancers in proniosomal formulations of nisoldipine, a calcium channel blocker with poor oral bioavailability due to hepatic metabolism. By incorporating lecithin, oleic acid, and propylene glycol, they achieved significant enhancement in transdermal drug permeation. The combination of oleic acid with propylene glycol produced the greatest improvement compared to other enhancers tested.⁴⁶ In conclusion, elastic vesicles, niosomal gels, and proniosomes represent the latest advances in transdermal niosomal technology. These systems provide better drug



stability, enhanced penetration, and improved patient compliance compared to conventional niosomes.

Clinical Trials investigated on Niosomal formulations⁴⁷

Table.3 Niosomal formulations in Clinical Trials

Drug / Active	Condition / Disease	Dosage Form	Dose (if reported)	Route of Administration
Dexmedetomidine (DEX-NANO)	Post-operative pain in pediatric cancer patients (bone marrow biopsy/aspiration)	Niosomal rectal formulation	Not specified (nano-rectal preparation)	Rectal
Papilocare (HA + β -glucan in niosomes)	HPV-related cervical lesions, cervico-vaginal mucosa repair	Vaginal gel	Applied once daily (per trial protocol)	Vaginal
Zinc sulfate (niosomal 2%) + cryotherapy	Common warts (verruca vulgaris)	Topical / intralesional preparation	2% zinc sulfate niosomal solution	Topical / Intralesional
Curcumin (CUR-NIO, 0.1%)	Psoriasis (localized skin lesions)	Niosomal gel	0.1% curcumin applied topically	Topical
Benzoyl peroxide + Clindamycin (niosomal)	Acne vulgaris	Niosomal lotion	-	Topical (facial)
Kopexil 1% vs Minoxidil 2% (niosomal)	Androgenic alopecia (hair loss)	Niosomal lotion	Kopexil 1% lotion / Minoxidil 2% lotion	Topical (scalp)

Challenges and Future Perspectives in Niosomal Drug Delivery

⁴⁸One of the major challenges in niosomal drug delivery is ensuring biocompatibility while minimizing potential toxicity. Although niosomes are generally regarded as safe, issues such as cytotoxicity, immune responses, and the long-term effects of repeated administration need to be carefully evaluated. Future research must therefore emphasize the optimization of lipid composition, surface modification techniques, and formulation parameters to improve safety and enhance tolerability for clinical applications. Alongside these concerns, regulatory hurdles also present a significant barrier to the successful translation of niosomal formulations from laboratory research to patient care. Approval requires comprehensive preclinical and clinical data to establish safety,

efficacy, and quality. ⁴⁹To overcome these obstacles, efforts should be directed toward standardizing evaluation criteria, streamlining approval processes, and strengthening collaborations between academic researchers, industry stakeholders, and regulatory authorities, thereby accelerating the pathway toward commercialization.

⁵⁰Looking ahead, several promising directions are shaping the future of niosomal drug delivery. The emergence of multifunctional niosomes marks a significant advancement, as these carriers are designed to simultaneously perform multiple tasks such as targeted drug delivery, imaging, diagnostics, and therapeutic monitoring. Their versatility lies in the incorporation of functional elements like targeting ligands, imaging agents, and stimuli-responsive polymers, which enable



site-specific action and controlled drug release. These systems have shown great potential in cancer therapy, infectious diseases, central nervous system disorders, and cardiovascular conditions, where improved delivery efficiency which can lead to superior treatment outcomes.⁵¹ However, the complexity of design, potential toxicity of added functional components, and regulatory concerns for combination products remain challenges that need to be addressed.

Another important direction is the integration of personalized medicine approaches, where treatments are tailored to the unique genetic, physiological, and environmental characteristics of individual patients. Niosomes, owing to their flexibility and tunable properties, are well-suited to support precision medicine by enabling customized drug delivery regimens that optimize efficacy while minimizing side effects. Similarly, the integration of nanotechnology into niosomal systems is opening new opportunities to enhance their performance.⁵² The incorporation of nanomaterials, hybrid Nano systems, and advanced nanoscale fabrication techniques allows precise control over vesicle size, morphology, and

release properties, while surface engineering strategies such as PEGylation or ligand attachment can improve targeting and circulation time. Furthermore, advanced analytical tools such as atomic force microscopy, dynamic light scattering, and electron microscopy provide critical insights into niosome structure and behaviour, thereby supporting the design and quality control of more efficient systems⁵³.

Finally, the advancement of niosomal drug delivery technologies depends heavily on collaboration and financial support.⁵⁴ Strong partnerships between academia, industry, and government agencies are essential to bridge the gap between laboratory research and clinical application. Interdisciplinary projects, technology transfer initiatives, and joint funding programs will play a pivotal role in sustaining innovation and ensuring that promising niosomal formulations can successfully progress to commercial and therapeutic use.⁵⁵

Drugs in Niosomal Delivery Systems: Route of administration, Indications, Dosage Forms, and Dose.

Table.4 Different Niosomal Drug Delivery Systems

Route of Administration	Drugs (in Niosomes)	Disease/Condition	Dosage Form	Dose (In Studies/Trials)
Intravenous	Doxorubicin	Breast cancer, lymphomas	Niosomal injection	50–75 mg/m ² every 3 weeks
	Camptothecin	Colon & ovarian cancer	Niosomal IV injection	10–15 mg/m ² /day (clinical trial basis)
	Insulin	Diabetes mellitus	Niosomal IV injection	0.1–0.2 units/kg
	Zidovudine	HIV/AIDS	Niosomal injection	1–2 mg/kg every 4 hours
	Cisplatin	Solid tumours (lung, ovarian, testicular)	Niosomal injection	50–100 mg/m ² every 3–4 weeks
	Rifampicin	Tuberculosis	Niosomal IV formulation	10 mg/kg daily
Inhalation	All-trans retinoic acid	Lung cancer, acute promyelocytic leukaemia (APL)	Niosomal aerosol/inhalation suspension	45 mg/m ² /day



Transdermal	Piroxicam	Rheumatoid arthritis, osteoarthritis	Niosomal gel/patch	20 mg/day (topical equivalent)
	Estradiol	Hormone replacement therapy	Niosomal patch/gel	0.05–0.1 mg/day
	Nimesulide	Inflammation, pain	Niosomal gel	100 mg/day equivalent
Ocular	Timolol maleate	Glaucoma, ocular hypertension	Niosomal eye drops	0.25–0.5% solution, 1 drop twice daily
	Cyclopentolate	Mydriasis (eye examination)	Niosomal eye drops	1% solution, 1–2 drops
Nasal	Sumatriptan	Migraine	Niosomal nasal spray	20 mg single dose (repeat after 2 hrs if needed)
	Influenza vaccines	Influenza prevention	Niosomal nasal vaccine	15 µg hemagglutinin per strain

CONCLUSION

Niosomes, formed from non-ionic surfactants, are emerging as one of the most effective vesicular drug delivery systems due to their safety, stability, low cost, and ability to encapsulate both hydrophilic and hydrophobic drugs. They enhance solubility, permeability, and bioavailability while reducing toxicity and side effects. Compared to liposomes, niosomes are more chemically stable, economical, and easier to manufacture, making them a promising alternative. They can be prepared using methods such as hand shaking, sonication, and ether injection, and have applications in targeted, ocular, topical, parenteral, and transdermal drug delivery. Niosomal gels, in particular, show improved skin penetration, retention, and therapeutic efficacy, making them suitable for treating fungal infections, eye diseases, and acne. Their “reservoir effect” allows prolonged drug release at the site of action.

Recent Clinical trials on niosomal formulation serves as a next generation drug delivery system with potential significance in localized therapy, oncology and dermatology as they have ability to combine safety, efficacy and patient acceptability which serves as the promising platform for future

pharmaceutical innovation. However larger, well-controlled clinical studies are also an essential components to establish long-term safety, comparative effectiveness, and regulatory acceptance.

The niosomal drug delivery system have a diverse route of administration like intravenous anticancer agents like doxorubicin, cisplatin, as they have ability to encapsulate both lipophilic drugs and hydrophilic molecules. They can also be given through non-invasive routes like transdermal patches, gels, ocular drops, inhalation aerosols, and nasal sprays which offers targeted drug delivery, improves drug pharmacokinetic parameters including bioavailability and reduces toxicity and overall enhances patient compliance.

Niosomes are not only limited to parenteral delivery, but they represent a platform technology which has the capability of addressing in cancer therapy, infectious diseases, hormonal replacement, pain management and vaccination. They can be the next generation drug delivery system as they have ability to cross the biological barriers especially in the brain and provides a controlled drug release system.



Niosomes are consistently compared with liposomes as they have similar vesicular drug delivery system, they have similar structural and functional characteristics and pharmaceutical applications. These are not compared with aquasomes or electrosomes as they are significantly different in structure, composition and function. As aquasomes have a three layered solid nanoparticle structure and electrosomes have lipid vesicles and are electrically charged as they have ion channels or enzymes they cannot be compared with other nano particulate carriers.

In summary, niosomes represent a versatile, stable, and cost-effective drug delivery system with significant advantages over conventional dosage forms. Their ability to improve targeting and therapeutic outcomes makes them one of the most promising nanocarriers in modern pharmaceutical and healthcare applications.

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