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# PREPARATION OF SOLID LIPID NANOPARTICLES USING VARIOUS METHODS

**Barsha Deb* and Jyoti Sharma**

Department of Pharmaceutics, University Institute of Pharma Sciences, Chandigarh University, Gharun, Mohali, Punjab-140413, India.

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***Corresponding Author**
**Barsha Deb**
Department of Pharmaceutics, University Institute of Pharma Sciences, Chandigarh University, Gharun, Mohali, Punjab-140413, India.

## ABSTRACT

Solid lipid nanoparticles are at the forefront of the rapidly evolving field of nanotechnology, with a wide range of applications in drug delivery, clinical medicine, testing, and other fields of science. Lipid nanoparticles can assist in the production of new therapeutics leading to their size-dependent properties. The capability to fuse drugs into nanocarriers opens up a whole new framework for drug delivery that could be used for optional and tertiary stages of treatment. Henceforth, solid lipid nanoparticles currently hold a lot of potential for fulfilling the target of controlled and site-specific drug delivery, and they've gotten a huge amount of attention from scientists. The underlying contrasts of different sorts of nanocarriers that depend on strong lipid, such as strong lipid nanoparticles, nanostructured lipid transporters, and lipid drug forms, are analyzed. Multiple categories of solid lipid nanoparticles, along with their synthesis methods and applications in various fields, are discussed here.

**KEYWORDS**: Solid lipid nanoparticles (SLNs); colloidal drug carriers; biodistribution; drug targeting.

## INTRODUCTION

The bioavailability of drugs taken orally is primarily determined by their lipid solubility in the GI tract and their permeability across cell membranes. Also, if a solution-based drug is chosen for pharmacological, pharmacokinetic, and toxicological studies during the drug development stage. So, a drug's biological application is limited, but it also poses a challenge to its pharmaceutical production at various stages.[1]

Nanotechnology has brought revolution by transforming the drug delivery market. Nanoparticles (NPs) in the size range of 10 to 1000 nm have improved the delivery of many drug molecules, especially chemotherapeutic agents. It provides various, innovative solutions to many problems relating to drug safety and efficacy. NPs have a number of unique characteristics that make them ideal drug carriers. A contrast between the 2 types highly favours the lipid NPs; firstly, they have challenges provided with the polymeric NPs like cytotoxic effect and therefore the lack of suitable methods for large-scale production. The first generation of lipid-based NPs was reported within the early 1990s and is understood as solid lipid nanoparticles (SLNs). Many types of NPs used as drug carriers are generally, but not certainly, made up of polymer matrix or lipoproteins[2]

**The following are some of the benefits of encapsulating drugs in nano-carriers**

i. Drugs that are sparingly soluble or hydrophobic have a faster dissolution rate.
ii. Surface functionalization designed to allow targeted drug delivery and immune system deception, thus trying to prolong in vivo therapeutic half -life.
iii. Controlled and sustained drug release, which, when combined, results in lower dosing frequency and greater therapeutic efficacy.

Solid lipid nanoparticle (SLNs) is typically spherical in structure with an average diameter between 10 and 1000 nanometers. Solid lipid nanoparticles are usually composed of a solid lipid core matrix capable of solubilizing lipophilic molecules. Surfactants help to keep the lipid core stable (emulsifiers). The LNs not only enhance the mucosal adhesion but also improve their GIT interval. There are two types of LNs with a rigid matrix: solid lipid nanoparticles (SLN) and nanostructured lipid carriers (NLC). Furthermore, their hydrophobic heart creates an ideal habitat for hydrophobic drugs to be entrapped, increasing bioavailability. The first generation of lipid-based NPs, known as SLNs, was discovered in the early 1990s. LNs have been used in pharmaceutical science for a number of times.[1,3]

A variety of drug nanocarriers have evolved to aid in the development of medical therapies, especially for the delivery of regulated drugs, genes or gene expression-modifying compounds, or vaccine antigens to a specific target site. As a part of nanocarriers, most commonly used nanoparticles are lipid-based and polymeric nanoparticles. Non-toxic self-assembly vesicles with a unilamellar or multilamellar structure, such as niosomes and liposomes, can encapsulate hydrophobic/hydrophilic therapeutic agents. Micelles, or polymeric nanoparticles, are colloidal carriers made up of biodegradable polymers.[2,4]

Figure 1 Represent the different SLNs based targeting system.

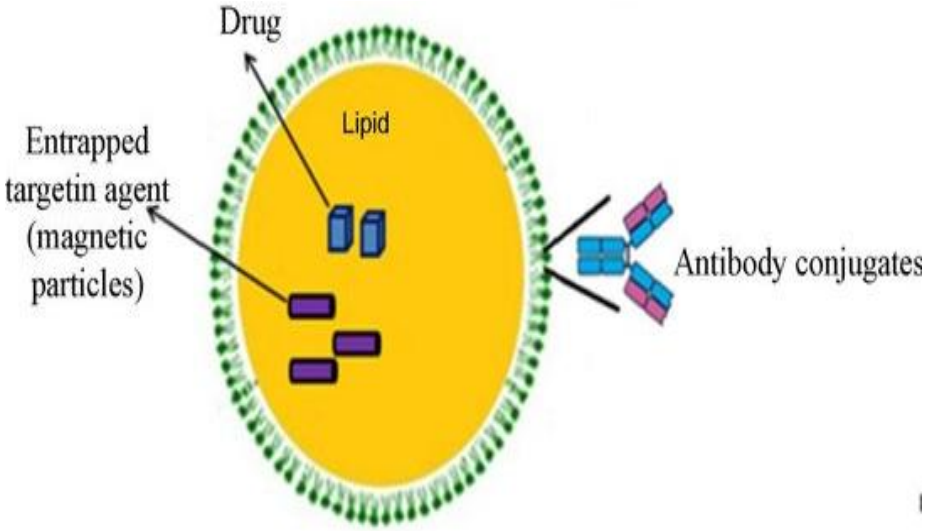


**Figure 1: The schematic representation of SLN targeting system.**[3]

## 1. Solid lipid nanoparticles

Solid lipid nanoparticles (SLNs) is one of the promising pharmaceutical nanocarriers which helps in controlled drug delivery. SLNs are usually composed of biodegradable lipidic components.The significant SLNs feature is that they will carry therapeutics sorts including small drug molecules, large biomacromolecules (polysaccharides, etc.), and genetic material (deoxyribonucleic acid/small interfering ribonucleic acid), and vaccine antigens too. They can load both hydrophilic and lipophilic drugs among the small drug molecules. Solid lipid nanoparticles are nanosphere or lipospheres is focused on the chemical nature of the active component and lipid, nature and concentration of emulsifiers, the drug solubility within the melted lipid.[4] Figure 2 &3 represents three various types of SLNs and NCLs.

### Types of SLNs

**Type I Homogeneous matrix model-** It is defined as the uniform matrix model because the API is molecularly diffused in the lipid core or is present in the amorphous form cluster heads and it is obtained when using optimized different API ratios and lipid passing through the High-Pressure Homogenization (HPH) technique at above the lipid freezing point, or when using the cold HPH technique.SLN Type I can have regulated release properties due to their structure.[1]

**Type II Drug enriched shell model-** It is obtained when the API concentration in the melted lipid is minimal. After implementing, the technique during the freezing of the homogenized

nano-emulsion, the lipid phase precipitates first, resulting in rapidly increasing the concentration of API within the lipid melt with elevated crystalized lipid fraction. When the API reaches its saturation solubility within the remaining melt, an outer shell containing both API and lipid solidifies around this centre. This model is not desirable for prolonged API release; however, due to the occlusive properties of the lipid centre, it will be favored to obtain a burst release of API.[1,2]

**Type III Drug enriched core model** – It is obtained when the recrystallization mechanism is that the vice versa of that type II model. In this process, a drug is solubilized inside the lipid melt on the verge of saturation solubility in this process. Following that, cooling of the lipid emulsion induces drug super-saturation within the lipid melt, resulting in drug recrystallization prior to lipid recrystallization. Additional cooling causes lipid recrystallization, forming a membrane around the drug-enriched centre that has already crystallized. This structural model is appropriate for drugs that need a long-term release.[1,5]

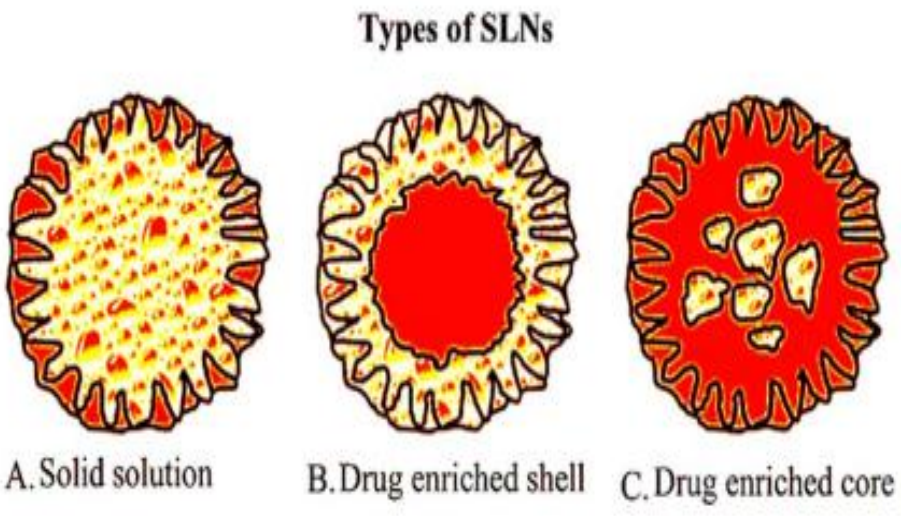


**Figure 2: Different types of SLNs.[1]**

**Types of NLCs**

1. **Imperfect (Imperfectly structured solid matrix)** - It is an inaccurate crystal model in which the matrix contains several voids and vacancies in which the API can be kept. Particles are achieved when blending solid lipids with an adequate amount of liquid lipids (oils). Because of the various chain length of the carboxylic acid and therefore, the matrix of NLCs, which is made up of monoacylglycerols, diacylglycerols, and triacylglycerols,

isn't ready to form a highly ordered structure, leaving open spaces (structural imperfections).[1]

2. **Amorphous (Structureless solid amorphous matrix)** - It is made by combining special lipids that do not recrystallize after homogenization and cooling of the nanoemulsion (hydroxyl octacosanyl hydroxy stearate, isopropyl myristate, dibutyl adipate). These lipids build amorphous matrices and maintain them over time, reducing API expulsion during storage.[1,6]

3. **Multiple (Multiple oils in fat in water)** - Lipophilic drugs have a greater solubility in liquid lipids (oils) than in solid lipids. This principle is frequently used to build NLCs of the "different" form. Higher quantities of oil are blended in strong lipids in this form of NLCs. Oil molecules spread readily in the lipid matrix at low concentrations. Phase separation occurs when oil is added in amounts greater than its solubility, resulting in small oily nano-compartments surrounded by a solid lipid matrix. The lipid matrix prevents drug leakage in these models, allowing for regulated drug release. Multiple types of NLCs are produced during the cooling phase of a hot homogenization process, and lipophilic drugs are often solubilized in oils.

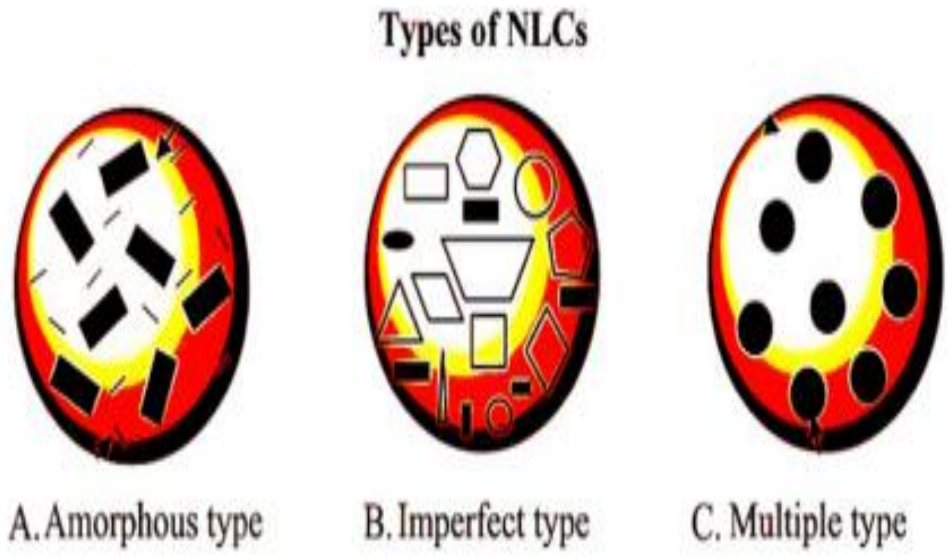


**Figure 3: Different types of NCLs.[1]**

## 2. Methods for the preparation of SLNs

The solid lipid nanoparticles can be made in a variety of ways. We may adjust the synthesis to make it more suitable, applicable, and offer a higher yield potential for controlled

nanoparticle synthesis using the conventional process.[4] The various synthesis methods for SLNs are described below-

- High-pressure homogenization method
- Ultrasonic/high speed homogenization method
- Solvent evaporation method
- Solvent emulsification-diffusion/solvent emulsification evaporation method
- Supercritical fluid method
- Micro-emulsion based method
- Spray drying method
- Double emulsion method
- Precipitation method
- Solvent injection method
- Film ultrasound dispersion method
- Coacervation method

**2.1. High-pressure homogenization (HPH) method-** HPH technique is utilized for the fabrication of SLNs whose size range varies from 50-100nm.[2] HPH pushes a liquid with high force (100–2000 bar) through a contracted gap. The fluid accelerates on a very short distance at fast (>1000 Km/h).[2] Particles are disrupted by extremely high shear pressure and cavitation forces down to the sub - micron scale. Normally, lipid content which is utilized is up to 5-10%; however, up to 40% content has been investigated. Two general HPH methodologies are hot homogenization and cold homogenization shown in figure no. 4. Both forms of HPH operate on the same principle of combining the drug with a large amount of lipid melt. The jet-stream homogenizers and the piston-gap homogenizers are the two types of high-pressure homogenizers available. In this method, mechanism of particle formation occurs through 3 processes i.e.

- Powerful turbulent eddies cause high mechanical compression.
- Pressure around the homogenizer valves is reduced.
- Cavitation forces are extremely powerful.[2]

**a) Hot homogenization method** – It is one of the HPH techniques to prepare SLNs, Lipid is melted to around 5ºC above to its melting point, at that point, drug is dissolved or solubilised in the melted lipid and the drug containing lipid melt is dispersed in an aqueous surfactant solution at the same temperature. They obtained by pre-emulsion is

then skilled a high-pressure homogenizer. The result of this procedure is hot o/w emulsion and the cooling of this emulsion prompts the crystallization of the lipid and development of solid lipid nanoparticles. The limitation of this method is complete avoidance of drug exposure to high temperature is not possible, the merit of it is a valuable dispersing method but demerit is that it required extreme energy for process.[2,7] Figure 4 A represents the procedure of making SLNs by hot homogenization method.

**b) Cold homogenization method** - It is one of the HPH techniques to produce SLNs, the initial step is drug incorporation incorporated into melted lipid and then melted lipid is cooled up to solidification. The drug-containing lipid melt is rapidly solidified by cooling with dry ice or liquid nitrogen. Quick cooling favors homogenous drug distribution within the lipid material. The solid material is grinding by using a mortar mill and acquired lipid microparticle and dispersed in a cool surfactant at room temperature or below it. The solid matrix mimics drug portioning to the water phase. It has remarkable over hot homogenization since during storage of the aqueous solid lipid dispersion, the entrapment ability stays unaltered. In this method there is a limitation of not suitable for thermo-labile drug and advantages of its commercially available, no temperature induced drug degradation occurs.[2,3] Figure 4B represents the procedure of making SLNs by cold homogenization method.

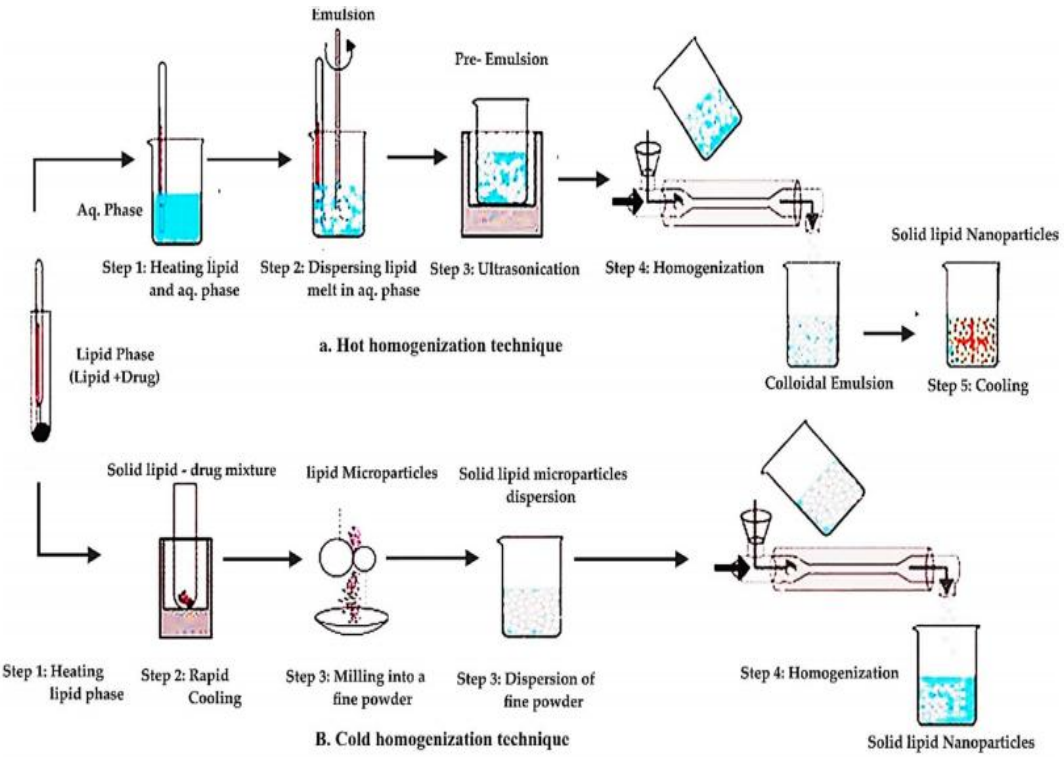


**Figure 4: A: Hot homogenization method.[2]**

**B:** Cold homogenization method.[2]

**2.2. Ultrasonication/high-speed homogenization method** - Ultrasonication is utilized to prepare SLNs of 50-100nm size[2] and it is a combination of both Ultrasonication and high-speed homogenization technique. It's also known as dispersing techniques. In the first step, the drug was mixed into melted lipid. The next step was to add the heated aqueous layer (heated to an equal temperature) to the melted lipid and emulsify it using probe sonication or a high-speed stirrer, or to add the aqueous phase to the lipid phase drop by drop accompanied by magnetic stirring. They used a probe test solicitor with a water bath (at 0ºC) to ultrasonicate the pre-emulsion. So as to prevent recrystallization during this procedure, the production temperature was kept at least 5-10°C over lipid melting point[2] The formulation was lyophilized to obtain freeze-dried powder and, at some point, mannitol was added to improve the formulation's stability. It is possible that the product will become contaminated with metal, which is a drawback. It has the benefit of being commercially available and reducing shear stress. The particle formation mechanism in this method is based on shear between adjacent particles, bubble growth, and implosive collapse due to cavitation forces.[8] Figure 5 represents the procedure of making SLNs by ultrasonication homogenization method.

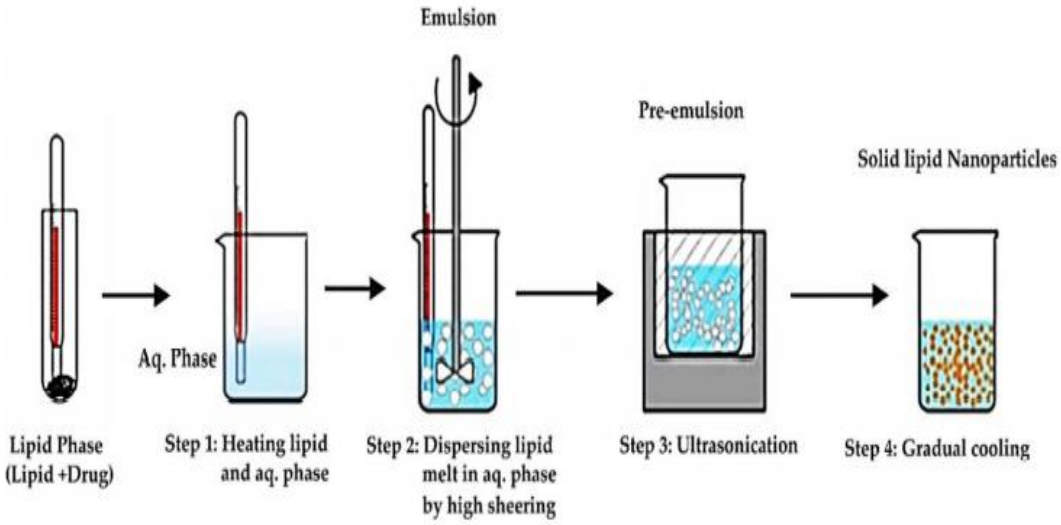


**Figure 5: Ultrasonication homogenization method.[2]**

**2.3. Solvent evaporation method** - It is an arrangement of emulsification by evaporation method to prepare SLNs which sizes ranges from 30 – 500nm.[1] The main lipophilic materials are dissolved in a water-insoluble organic solvent (e.g, cyclohexane) and emulsified in an aqueous process. Following the evaporation of the organic solvent, lipid

precipitation in the aqueous medium produces nano-particles with a mean size of 25 nm. High-pressure homogenization was used to emulsify the solution in an aqueous phase. The organic solvent was then evaporated from the emulsion at a reduced pressure (40–60 bars). The process is limited by the production of very dilute nanoparticle dispersion.[2,6] Figure 6 represents the procedure of making SLNs by solvent evaporation method.

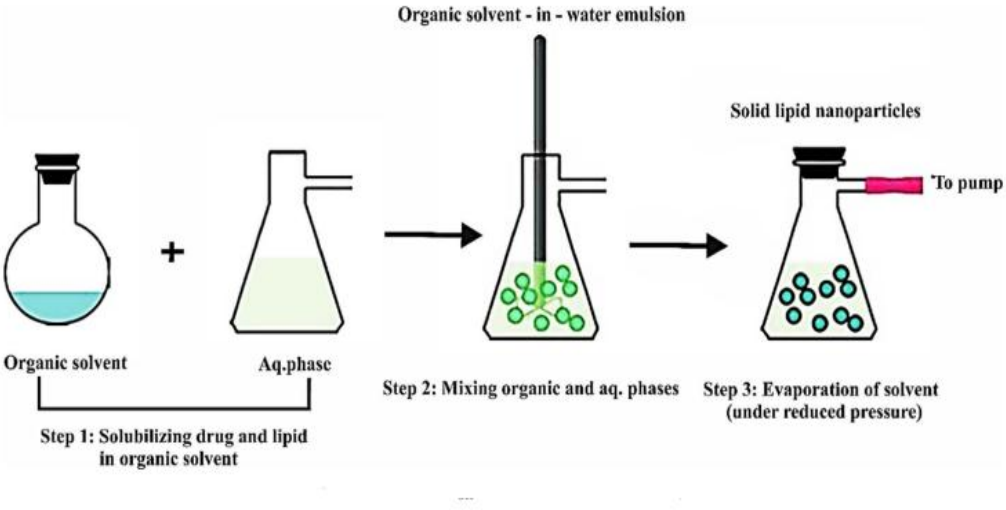


**Figure 6: Solvent evaporation method.[2]**

**2.4. Solvent emulsification-diffusion/solvent emulsification evaporation method**- It is a microemulsion association that is used to prepare SLNs.From this method, the lipid phase is dissolved in an organic solvent (acetone) then the organic phase is added to the aqueous stage under continuous mixing at 70–80ºC until the organic phase is completely at that point the obtained nanoemulsion is cooled (below 5ºC) to solidify lipid nanoparticles.[1] The solvent is vaporised below compressed pressure, resulting in a diffusion of nanoparticles produced by the precipitation of the lipid in the evaporated aqueous medium. The average diameters across of SLNs are 30–100 nm; and size ranges from 100 – 2000nm and It is depended upon the lipid concentration in the organic phase and the emulsifier utilized likewise have the highest encapsulation efficiency 67.9%, the solvent utilized (e.g. benzyl alcohol, butyl lactate, ethyl acetate, isopropyl acetate, methyl acetate). Throughout the operation, there was constant stirring. Finally, vacuum distillation or lyophilisation is used to remove the diffused solvent. The method's drawbacks include the possibility of metallic contamination of the product during sonication. The most significant benefit of this method is the avoidance of heat during training.[2,10]

Figure 7 represents the procedure of making SLNs by solvent emulsification-diffusion method.

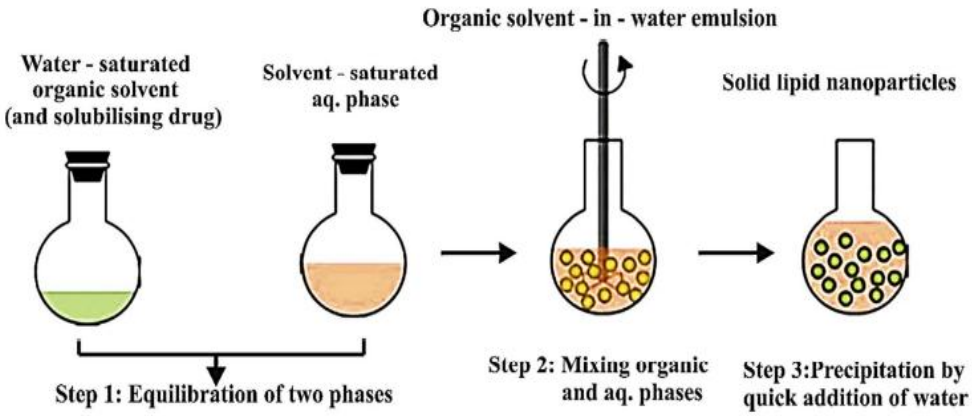


**Figure 7: Solvent emulsification-diffusion method.[2]**

**2.5. Supercritical fluid method** - This is one of the splitting methods for the production of SLNs which size ranges from 400 – 600nm, for example, the rapid growth of supercritical solution, particles from gas saturated solution, aerosol solvent extraction, and supercritical fluid extraction of emulsions.Solvent was removed from the emulsion using this technique by moving it through a column of supercritical CO2 in a parallel direction. The operating temperature and pressure decide the extraction quality.Currently, the drug is dissolved in molten lipid, emulsified with an aqueous surfactant solution, and then homogenised to obtain a fine emulsion. At that time, a purchased oil in water (o/w) emulsion was presented in the extraction column, and supercritical CO2 was applied from the bottom counter at a constant temperature (35ºC) and pressure (80 bar).[2] When an emulsion interacts with supercritical CO2, the organic phase develops due to the reverse motion of supercritical CO2 into the emulsion droplet, which causes the precipitation of lipid-drug content dissolved in the organic phase. When the pressure and temperature of a fluid reach their respective critical values, the capacity of the fluid to increase the dissolving limit of the compounds is referred to as supercritical. Solution for carbon dioxide.[2,11] Figure 8 represents the procedure of making SLNs by supercritical fluid method.

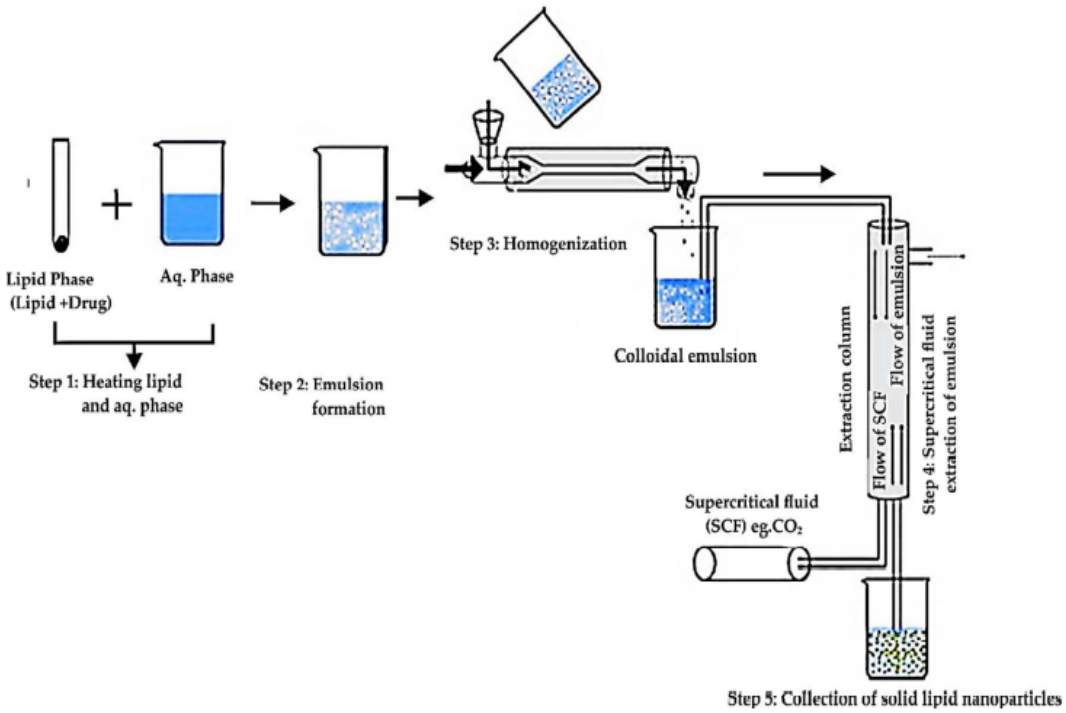


**Figure 8: Supercritical fluid method.**[1]

**2.6. Micro-emulsion-based method**- Micro-emulsion is utilized to prepare SLNs whose size range might be in between 50-300nm; the idea of the microemulsion procedure was first presented by Gasco in 1993, and furthermore patented by Mumper and Jay for this method, Mumper in 2006.[2] The production of SLNs is dependent on the micro-emulsion dilutions, and they are produced by stirring an optically transparent mixture at 65-70ºC. A low melting fatty acid, an emulsifier, co-emulsifiers, and water are commonly used. It's used in the production of o/w micro emulsion. However, the emulsifying wax is melted at 37–55° C, and the water is added at a similar temperature. after adding the surfactant in water, with limited mixing to obtain a uniform milky slurry of wax, In the liquid matrix phase, a steady and clear o/w microemulsion is formed. It is then cooled to room temperature or 4° C in order to precipitate SLNs. SLNs are gone through several processes. Benefits of its requirement Mechanical energy input is minimal, and the system is theoretically stable. However, it is highly responsive to change and needs time-consuming formulation. The particle forming mechanism in this process is lipid crystallisation due to rapid solidification.[2,12] Figure 9 represents the procedure of making SLNs by micro-emulsion based method.

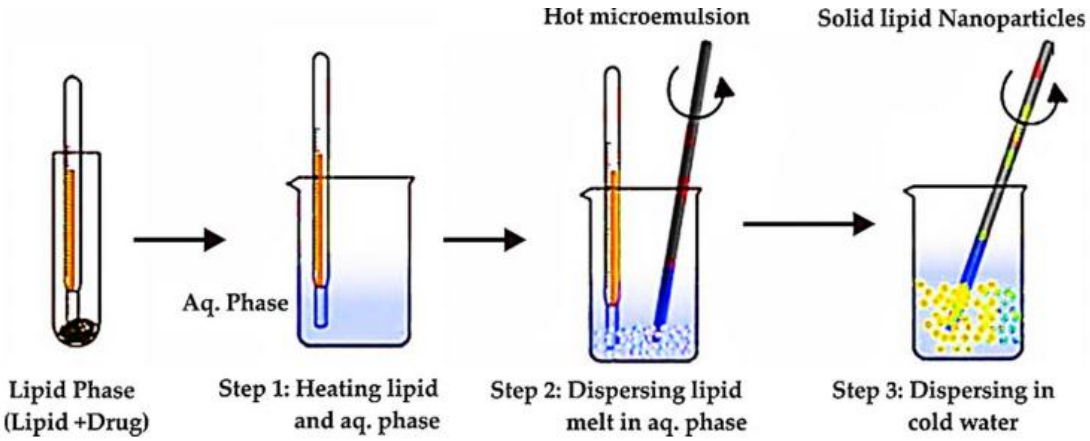


**Figure 9: Micro-emulsion based method.**[1]

**2.7. Spray drying method -** This method was introduced by Domb J. also, a colleague in 1995, as nanopellets.[2] It's basically the same as ultrasonication and lyophilization technique selection. SLNs can also be made in advance from an emulsion precursor in which the organic phase is made up of a solvent. It can be volatile or partially water-miscible, and O/W or W/O/W emulsions can be produced. O/W emulsions are used for lipophilic drugs that are dissolving in the system's inner organic process, along with the lipid. W/O/W emulsions are ideal for hydrophilic drugs that disperse in the inner aqueous phase and the lipid in the intermediate organic phase. When the solvent is extracted, either by evaporation or by water dilution (solvent diffusion technique for partial water-miscible solvents), lipid precipitates as nanoparticles encasing the medication. The SLNs size may be ranges from 3-10µm. It has the advantage of being a less expensive process than lyophilization, but it also causes particle aggregation due to the high temperature, which is a disadvantage.[2,13]

**2.8. Double emulsion method -** This is utilized to prepare SLNs ranging between 100-200nm[2] and it depends on solvent emulsification and an evaporation method, loaded with hydrophilic drugs has been introduced to the scientific community. From this method, In the internal water phase of a w/o/w two-fold emulsion, the hydrophilic drug is encapsulated with a stabilizer to avoid drug partitioning to the external water phase during solvent evaporation. Sodium cromoglycate-containing SLNs are made with it. The disadvantage is that it needs a large particle size in the final formulation as well as a high concentration. The mechanism of particle formation in this process is dependent on lipid crystallization due to solidification[2,14] Figure 10 represents the procedure of making SLNs by double emulsion method.

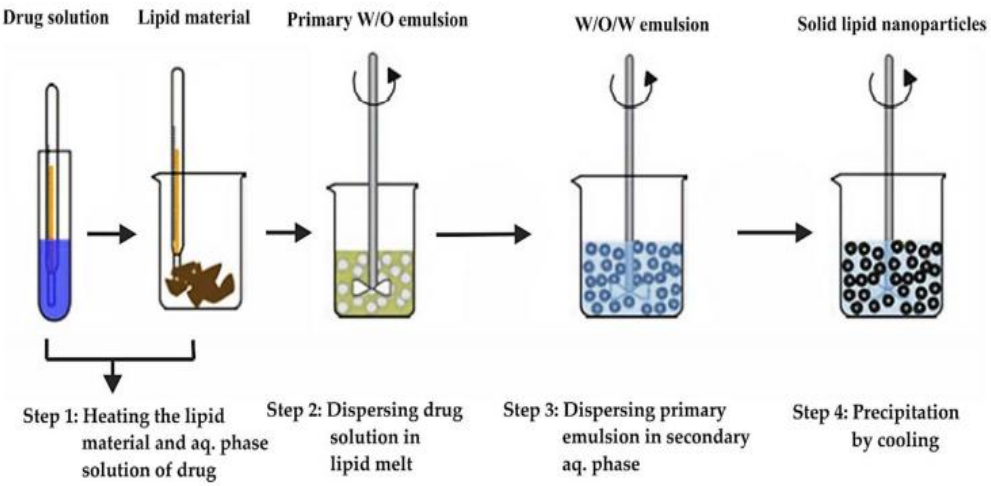


**Figure 10: Double emulsion method.[1]**

**2.9. Precipitation method -** Which is utilized to prepare SLNs whose size is 100-150nm, however for the characterization required solvents.[2] Glyceride is dissolved in an organic solvent in the first step, and then emulsified in an aqueous process in the second. The lipid precipitates nanoparticles framed after the solvent evaporates. The use of organic solvents, which need more as they evaporate, has a direct drawback, as has the larger particle size found in the formulation. On the other hand, it has the advantage of requiring no complex instrument, being simple to prepare, and being suitable for thermo-labile substance.[1]

**2.10. Solvent injection method -** This technique is used to make SLNs (whose size is between 100-500nm), The solvent injection method's fundamental guide line is similar to that of the solvent diffusion method. Lipids are dissolved in a water-miscible solvent (e.g., acetone, isopropanol, and methanol) or a water- (miscible solvent) mixture and easily injected into an aqueous solution containing surfactants using an injection needle in this process. Dropping a lipid-solvent droplet into water reduces the size of the droplet while also increasing the lipid concentration. Currently, the lipid and therefore the drug are dissolved in a water miscible organic solvent (ethanol, acetone, isopropanol) and then inserted through a syringe needle into water when stirring. The lipid precipitates as nanoparticles when it comes into contact with water, encapsulating the drug. The lipid form, surfactant, and solvent dissolvable used, as well as the viscosity of the outer phase, all have an impact on particle size. Various procedure parameters, such as injected solvent, lipid concentration, injected volume of solvent, lipid concentration in the solvent phase, and aqueous phase viscosity, influence and monitor the particle size of SLNs in

this process. The mechanism of particle formation in this process is lipid crystallization caused by rapid solvent diffusion from the internal organic phase to the external aqueous phase. Figure 11 represents the procedure of making SLNs by solvent injection method.

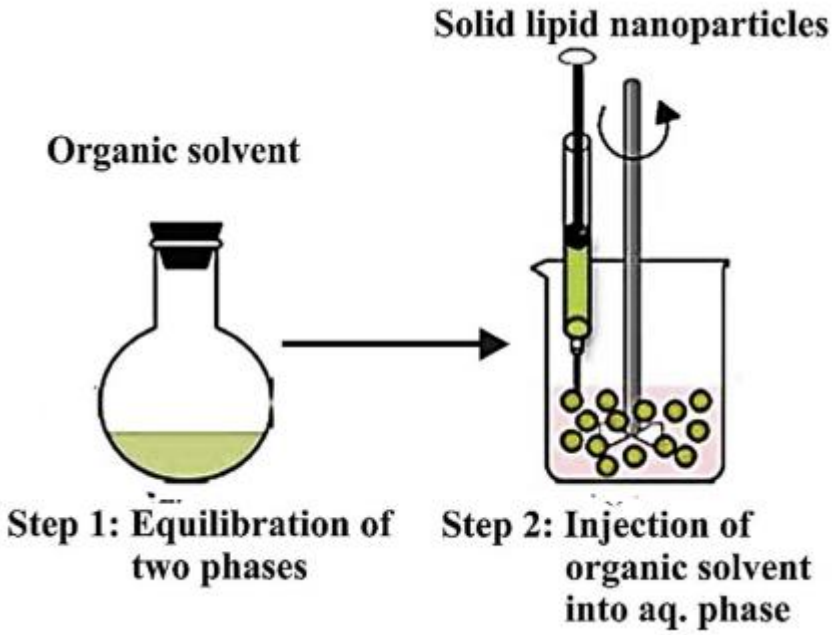


**Figure 11: Solvent injection method.**[1]

**2.11. Film ultrasound dispersion method -** The lipid and drug were placed in suitable organic solutions, and after decompression, rotation, and evaporation of the organic solutions, a lipid film was formed, followed by the addition of the solution containing the emulsions. Finally, the SLNs with the small and uniform molecule size are framed in between 93-164nm using ultrasound with the probe to the diffuser.[2,15]

**2.12. Coacervation method –** It's used to make SLNs of 200-1000nm[2] by heating the polymer in water, after cooling to room temperature, the lipid substance was dispersed in polymeric stabilizer stock solution, and the mixture was heated with constant stirring just above the lipid Kraft point of the sodium salt of the fatty acid, yielding a transparent solution. The drug solution was mixed with a warm aqueous lipid solution or a transparent solution until a single phase was obtained. A suspension was created by adding an acidifying solution (coacervating solution) dropwise until the desired pH was reached. The suspension was instantly cooled in a water bath while being constantly mixed. The aqueous and organic phases were housed in the thermo-stated bath to

maintain the desired temperature, and nitrogen was used to create the liquid phase's pressure, basically, the process comprises of three stages[2]

1) At 55–70ºC, melt a pharmaceutically suitable matrix containing lipid(s), surfactant(s), polymer(s), and medication.
2) To make the o/w micro emulsion, add pre-heated water when stirring.
3) To make the SLNs, cool to room temperature when stirring.

The lipid or lipid mixture is placed in a nitrogen-filled thermo-stated pressurised reservoir. The melted material is moved through a membrane contactor in an infinite flow. The oily phase forms nanodroplets on the inner membrane surface, which are swept away by the heated surfactant solution. Cooling the nanoemulsion produces nanoparticles. Cross-flow velocity is the most important parameter for controlling particle size in the aqueous process. Without a doubt, circulating the aqueous phase flow allows for faster separation of the smooth beads, resulting in a reduction in their size. The lipid phase strain, which has a direct effect on lipid phase flux, is another significant parameter for regulating particle size. As a consequence, as the pressure rises, the particle size decreases. Furthermore, particle size decreases with increasing temperature and lipid content. The liquid phase was forced through the membrane pores at a temperature above the lipid melting point, allowing tiny droplets to form. The formation of SLNs was achieved by cooling the preparation to room temperature. The method is scalable, and the particle size can be adjusted by using various pore sizes in the membranes. Its benefits include a solvent-free technique, the elimination of the need for complicated equipment, and the elimination of waste. Avoids high temperatures, and it's simple to make. Appropriate for thermo-labile materials Hydrophilic drug hydrophobic ion pairs were successfully applied. However, problems occur when scaling up production requires a large volume of organic solvent, and solvent toxicity can be detected in the final product. In this process, a decrease in the pH of alkaline salts of fatty acids in micellar solution caused by acidification (coacervating solution) in the presence of a polymeric stabiliser induces proton exchange and lipid precipitation.[16] Figure 12 represents the procedure of making SLNs by coacervation method.

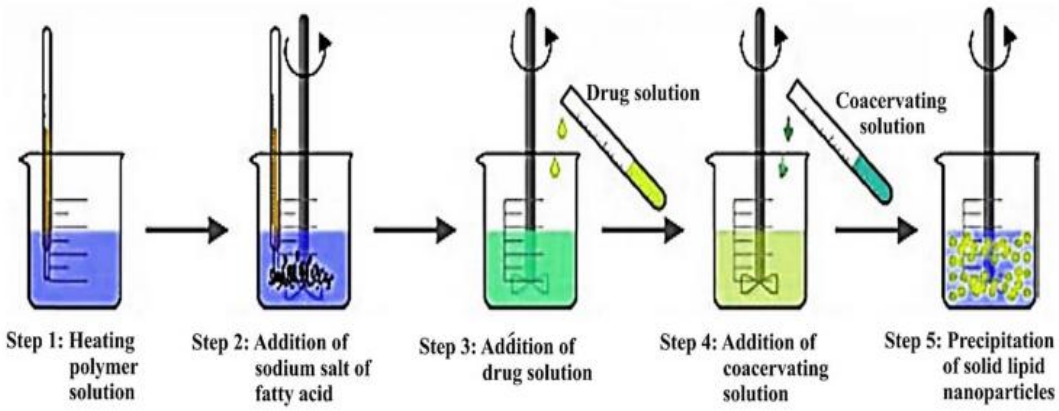


**Figure 12: Coacervation method.**[1]

**Applications of SLNs in different disease treatment**

As compared to liposomes, solid lipid nanoparticles have a higher level of stability and are easier to scale up. This property may be crucial for a variety of targeting scenarios. Colloidal drug delivery systems are made up of SLNs, which are biodegradable and can be stored for at least a year. SLNs have a variety of possible applications, some of which are mentioned below:

**1. Gene vectors are delivered using SLNs.**

SLN can be used in the development of gene vectors. For example, the insertion of a diametric HIV-1 HAT peptide (TAT 2) into the SLN gene vector, optimised gene transfer. SLN has been seen carrying genetic/peptide materials such as DNA, plasmid DNA, and other nucleic acids, according to various news sources. The lipid nuclic acid nanoparticles were made from a liquid nanophase containing water and a water miscible organic solvent in which both the lipid and the DNA were separately dissolved and then the organic solvent was removed, resulting in stable and homogeneously sized lipid-nuclic acid nanoparticles (70-100 nm). It's known as genospheres. The addition of an antibody-lipo polymer conjugated particle in the particle allows it to be targeted specifically.[15]

**2. SLNs for transdermal use**

Tropolide, imidazole antifungals, anticancers, vitamin A, isotretinoin, ketoconazole DNA, flurbiprofen, and glucocorticoids have also been applied to the skin using SLNs and NLCs. The epidermal targeting is caused by podophyllotoxin-SLN penetration into the stratum corneum and skin surface. Vitamin A-loaded nanoparticles can be made with glyceryl behenate. The methods can be used to increase penetration with long-term release. Isotretinoin-loaded lipid nanoparticles were developed for topical drug delivery. For the hot

homogenization process, soyabean lecithin and Tween 80 are used. Because of the increased accumulative absorption of isotretinoin in the skin, the procedure is beneficial. The flurbiprofen-loaded SLN gel for topical application has a number of potential benefits, including delivering the drug directly to the site of action, resulting in higher tissue concentrations. For the preparation of this form of SLN gel, polyacrylamide, glycerol, and water were used.[15]

### 3. In the cosmetics industry, SLNs are used to

The SLNs have been used as an active carrier agent for molecular sunscreens and UV blockers, as well as in the preparation of sunscreens. The addition of 4% SLN to a traditional cream improved skin hydration by 31% after 4 weeks, according to an in vivo report. SLN and NLCs have proven to be revolutionary occlusive topicals with controlled release. In comparison to traditional formulations, glyceryl behenate SLNs have improved vitamin A localization in the upper layers of skin.[15]

### 4. SLNs in agriculture

When essential oil extracted from Artemisia arboreseens L was combined with SLN, it was able to minimise rapid evaporation when compared to emulsions, and the systems have been used in agriculture as a suitable carrier of environmentally friendly pesticides. The SLN were made with compritol 888 ATO as the lipid and poloxamer 188 or Miranol Ultra C32 as the surfactant.[15]

### 5. SLNs as a targeted anticancer drug carrier in solid tumours

SLNs have been shown to be effective as drug carriers in the treatment of neoplasms. Tamoxifen, an anticancer medication, is inserted in SLN to increase the permeability and retention impact of the drug during i.v. administration in breast cancer. SLNs filled with drugs including methotrexate and camptothecin have been used to target tumours.[15]

### 6. SLNs in breast Cancer and Lymph node metastases

Mitoxantrone-loaded SLN local injections were developed to minimise toxicity while also increasing drug safety and bioavailability. Incorporation of doxorubicin (Dox) in SLNs has been shown to improve efficacy. Dox was complexed with a soybean-oil-based anionic polymer and then dispersed in water with a lipid to form Dox-loaded stable lipid nanoparticles. The system's effectiveness has been improved, and breast cancer cells have been reduced.[15]

### 7. Oral SLNs in antitubercular chemotherapy

Antitubercular drugs like rifampicin, isoniazid, and pyrazinamide-loaded SLN systems reduced dosing frequency and improved patient compliance. Antitubercular drug-loaded solid lipid nanoparticles are produced using the emulsion solvent diffusion technique. The nebulization of the above drug in SLN was also documented to improve the drug's bioavailability in animals.[15]

## CONCLUSIONS

Due to the rapidly developing field of nanotechnology, SLNs are used for a variety of benefits to researchers, including drug delivery, sufficient attention to the site of action in a regulated and continuous manner, plausible scale-up, and the absence of burst effects, making them more relevant than other nano-particle techniques. The biggest potential for future application of different types of drug delivery and chronic diseases. The SLNs have the ability to achieve these broad goals, at least in part. SLNs are an excellent way to accomplish the standard goal of managed drug delivery. They are relatively new drug delivery technologies that have gotten a lot of attention since the early 1990s, and the future looks bright for their systemic investigation and abuse.[17]

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