



## Nanosuspension: A Review

Rupali L. Shid\*, Shashikant.N.Dhole, Nilesh Kulkarni, Santosh L. Shid  
 Modern College of Pharmacy (For Ladies) Moshi, Pune University, India.  
 \*Corresponding author's E-mail: [rupalishid23@gmail.com](mailto:rupalishid23@gmail.com)

Accepted on: 13-06-2013; Finalized on: 31-08-2013.

### ABSTRACT

Solubility is the crucial factor for drug effectiveness, independence of the route of administration. Large proportions of newly discovered drugs are water insoluble, and therefore poorly bioavailable contributing to deserted development effort. These so-called 'Brickellia' candidates can now be delivered by formulating them into Nanosuspension. Nanosuspension technology solved the problem of drugs which are poorly aqueous soluble and less bioavailability. Stability and bioavailability of the drugs can be improved by the Nanosuspension technology. Preparation of Nanosuspension is simple and applicable to all drugs which are aqueous insoluble. Nanosuspensions are prepared by using wet mill, high pressure homogenizer, emulsion-solvent evaporation, melt emulsification method and super critical fluid techniques. Nanosuspension can be prepared by using stabilizers, organic solvents and other additives such as buffers, salts, polyols, osmogent and cryoprotectant. Nanosuspensions can be delivered by oral, parenteral, pulmonary and ocular routes. Nanosuspensions can also be used for targeted drug delivery when incorporated in the ocular inserts and mucoadhesive hydrogels.

**Keywords:** Dissolution, Nanosuspension, Saturation solubility, Solubility enhancement, Surfactant.

### INTRODUCTION

#### Nanosuspension

More than 40% of the new chemical entities being generated through drug discovery programmes are poorly water-soluble or lipophilic compounds. Formulating a poorly water soluble drug has always been a challenging problem confronted by the pharmaceutical scientist. The formulation of nano-sized particles can be implemented to all drug compounds belonging to biopharmaceutical classification system (BCS) classes II and IV to increase their solubility and hence partition into gastrointestinal barrier. Micronization is used for class II drugs of (BCS), i.e. drugs having a good permeability and poor solubility.<sup>1-5</sup> There are many conventional methods for increasing the solubility of poorly soluble drugs, which include micronization,<sup>6</sup> solubilization using co-solvents, salt form, surfactant dispersions, precipitation technique, and oily solution. Other techniques are like liposomes, emulsions, microemulsion, solid dispersion and inclusion complexation using cyclodextrins<sup>6-12</sup> show sensible achiever, but they lack in universal applicability to all drugs. These techniques are not applicable for those drugs which are not soluble in aqueous and organic solvents. Nanotechnology can be used to solve the problems associated with these conventional approaches for solubility and bioavailability enhancement. Nanosuspension is favored for compounds that are insoluble in water (but are soluble in oil) with high log P value, high melting point and high doses. Nanosuspension technology can also be used for drugs which are insoluble in both water and organic solvents. Hydrophobic drugs such as Atorvastatin,<sup>13</sup> Famotidine,<sup>14</sup> Simvastatin,<sup>15</sup>

Revaprazan,<sup>16</sup> Aceclofenac,<sup>17</sup> are formulated as Nanosuspension.

Nanosuspensions are colloidal dispersions of nanosized drug particles stabilized by surfactants. They can also be defined as a biphasic system consisting of pure drug particles dispersed in an aqueous vehicle in which the diameter of the suspended particle is less than 1µm in size. The Nanosuspensions can also be lyophilized or spray dried and the nanoparticles of a Nanosuspension can also be incorporated in a solid matrix<sup>18-23</sup>.

Nano is a Greek word, which means 'dwarf'. Nano means it is the factor of 10<sup>-9</sup> or one billionth. Some comparisons of nanoscale are given below,

0.1 nm = Diameter of one Hydrogen atom.

2.5 nm = Width of a DNA molecule

1 micron = 1000 nm.

1 nm = 10<sup>-9</sup>m = 10<sup>-7</sup> cm = 10<sup>-6</sup> mm.

Micron = 10<sup>-6</sup>m = 10<sup>-4</sup> cm = 10<sup>-3</sup>mm 4.

For a long duration of time micronization of poorly soluble drugs by colloid mills or jet mills was preferred. The overall particle size distribution ranges from 0.1µm to approximately 25µm, only negligible amount being below 1µm in the nanometer range.

#### When to go for Nano Suspensions Approach

- Preparing nano suspensions is preferred for the compounds that are insoluble in water (but are soluble in oil) with high log P value.
- Conventionally the drugs that are insoluble in water but soluble in oil phase system are formulated in liposome, emulsion systems but these lipidic



formulation approaches are not applicable to all drugs. In these cases nano suspensions are preferred.

- In case of drugs that are insoluble in both water and in organic media instead of using lipidic systems Nanosuspensions are used as a formulation approach.
- Nanosuspension formulation approach is most suitable for the compounds with high log P value, high melting point and high dose.<sup>24,25</sup>

#### Potential Benefits of Nanosuspension Technology for Poorly Soluble Drugs

- Reduced particle size, increased drug dissolution rate, increased rate and extent of absorption, increased bioavailability of drug, area under plasma versus time curve, onset time, peak drug level, reduced variability, reduced fed/fasted effects.
- Nanosuspensions can be used for compounds that are water insoluble but which are soluble in oil. On the other hand, Nanosuspensions can be used in contrast with lipidic systems, successfully formulate compounds that are insoluble in both water and oils.
- Nanoparticles can adhere to the gastrointestinal mucosa, prolonging the contact time of the drug and thereby enhancing its absorption.
- A pronounced advantage of Nanosuspension is that there are many administration routes for Nanosuspensions, such as oral, parenteral, pulmonary, dermal and ocular.
- Nanosuspension of nanoparticles (NPs) offers various advantages over conventional ocular dosage forms, including reduction in the amount of dose, maintenance of drug release over a prolonged period of time, reduction in systemic toxicity of drug, enhanced drug absorption due to longer residence time of nanoparticles on the corneal surface, higher drug concentrations in the infected tissue, suitability for poorly water-soluble drugs and smaller particles are better tolerated by patients than larger particles, therefore nanoparticles may represent auspicious drug carriers for ophthalmic applications.
- Nanosuspension has low incidence of side effects by the excipients.
- Nanosuspensions overcome delivery issues for the compounds by obviating the need to dissolve them, and by maintaining the drug in a preferred crystalline state of size sufficiently small for pharmaceutical acceptability.
- Increased resistance to hydrolysis and oxidation, increased physical stability to settling.
- Reduced administration volumes; essential for intramuscular, subcutaneous, ophthalmic use.
- Finally, Nanosuspensions can provide the passive targeting.<sup>26-29</sup>

#### METHODS OF PREPARATION OF NANOSUSPENSION

Mainly there are two methods for preparation of Nanosuspensions. The conventional methods of precipitation (Hydrosols) are called 'Bottom up

technology'. The 'Top Down Technologies' are the disintegration methods and are preferred over the precipitation methods. The 'Top Down Technologies' include Media Milling (Nanocrystals), High Pressure Homogenization in water (Dissocubes), High Pressure Homogenization in non aqueous media (Nanopure) and combination of Precipitation and High-Pressure Homogenization (Nanoedge).<sup>22-29</sup>

1) Bottom-up technology

2) Top-down technology

#### Bottom-Up Technology

The term "Bottom-up technology" means that one starts from the molecular level, and goes via molecular association to the formation of a solid particle. That means that we are discussing classical precipitation techniques by reducing the solvent quality, for example, by pouring the solvent into a nonsolvent or changing the temperature or a combination of both. Precipitation is a classical technique in pharmaceutical chemistry and technology.<sup>30-34</sup>

#### Advantage

- 1) Use of simple and low cost equipment.
- 2) Higher saturation solubility is the advantage for precipitation compared to other methods of Nanosuspension preparation.

#### Disadvantages

- 1) The drug needs to be soluble in at least one solvent (thus excluding all new drugs that are simultaneously poorly soluble in aqueous and in organic media).
- 2) The solvent needs to be miscible with at least one non-solvent.
- 3) Solvent residues need to be removed, thus increasing production costs.
- 4) It is a little bit tricky to preserve the particle character (i.e. size, especially the amorphous fraction). In general, it is recommended that a second consecutive process has to be performed for particle preservation that is spray drying or lyophilization.<sup>35-37</sup>

#### Top-Down Technology

The top down technologies include

- a) Media milling
- b) High pressure homogenization

#### Media Milling

Nanosuspensions are produced by using high-shear media mills or pearl mills. The mill consists of a milling chamber, milling shaft and a recirculation chamber. An aqueous suspension of the drug is then fed into the mill containing small grinding balls/pearls. As these balls rotate at a very high shear rate under controlled temperature, they fly through the grinding jar interior and impact against the



sample on the opposite grinding jar wall. The combined forces of friction and impact produce a high degree of particle size reduction. The milling media or balls are made of ceramic-sintered aluminium oxide or zirconium oxide or highly cross-linked polystyrene resin with high abrasion resistance. Planetary ball mills (PM100 and PM200; Retsch GmbH and Co., KG, Haan, Germany) is one example of an equipment that can be used to achieve a grind size below 0.1  $\mu\text{m}$ . A Nanosuspension of Zn-Insulin with a mean particle size of 150 nm was prepared using the wet milling technique. The major drawbacks of this technology include the erosion of balls/pearls that can leave residues as contaminants in the final product, degradation of the thermolabile drugs due to heat generated during the process and presence of relatively high proportions of particles  $\geq 5 \mu\text{m}$ .<sup>38-41</sup>

#### Advantages

- Simple technology
- Low-cost process regarding the milling itself
- Large-scale production possible to some extent (batch process).

#### Disadvantages

- Potential erosion from the milling material leading to product contamination.
- Duration of the process not being very production friendly.
- Potential growth of germs in the water phase when milling for a long time.
- Time and costs associated with the separation procedure of the milling material from the drug nanoparticle suspension, especially when producing parenteral sterile products.<sup>38-41</sup>

### High Pressure Homogenization

#### Dissocubes

Homogenization involves the forcing of the suspension under pressure through a valve having a narrow aperture. Dissocubes was developed by Muller *et al.* in 1999. In this case, the suspension of the drug is made to pass through a small orifice that result in a reduction of the static pressure below the boiling pressure of water, which leads to boiling of water and formation of gas bubbles. When the suspension leaves the gap and normal air pressure is reached again, the bubbles implode and the surrounding part containing the drug particles rushes to the center and in the process colloids, causing a reduction in the particle size. Most of the cases require multiple passes or cycles through the homogenizer, which depends on the hardness of drug, the desired mean particle size and the required homogeneity. This principle is employed in the APV Gaulin Micron LAB 40 Homogenizer (APV Homogenizer, Lóbeck, Germany) and the NS 1001L-Panda 2K high-pressure homogenizer (Nirosuavi. S.P.A., Parma, Italy).

To produce a Nanosuspension with a higher concentration of solids, it is preferred to start

homogenization with very fine drug particles, which can be accomplished by pre-milling. The major advantage of high- pressure homogenization over media milling is that it can be used for both diluted as well as concentrated suspensions and also allows aseptic production.<sup>42-45</sup>

#### Nanopure

Nanopure is suspensions homogenized in water-free media or water mixtures. In the Dissocubes technology, the cavitation is the determining factor of the process. But, in contrast to water, oils and oily fatty acids have very low vapour pressure and a high boiling point. Hence, the drop of static pressure will not be sufficient enough to initiate cavitation. Patents covering disintegration of polymeric material by high- pressure homogenization mention that higher temperatures of about 80°C promoted disintegration, which cannot be used for thermolabile compounds. In nanopure technology, the drug suspensions in the non- aqueous media were homogenized at 0°C or even below the freezing point and hence are called "deep-freeze" homogenization. The results obtained were comparable to Dissocubes and hence can be used effectively for thermolabile substances at milder conditions.<sup>46,47</sup>

#### Nanoedge™

The basic principles of Nanoedge are the same as that of precipitation and homogenization. A combination of these techniques results in smaller particle size and better stability in a shorter time. The major drawback of the precipitation technique, such as crystal growth and long-term stability, can be resolved using the Nanoedge technology. In this technique, the precipitated suspension is further homogenized; leading to reduction in particle size and avoiding crystal growth. Precipitation is performed in water using water-miscible solvents such as methanol, ethanol and isopropanol. It is desirable to remove those solvents completely, although they can be tolerated to a certain extent in the formulation. For an effective production of Nanosuspensions using the Nanoedge technology, an evaporation step can be included to provide a solvent-free modified starting material followed by high-pressure homogenization.<sup>48</sup>

#### Emulsion Diffusion Method

Apart from the use of emulsion as drug delivering vehicle they can also be used as templates to produce Nanosuspension. The use of emulsions as templates is applicable for those drugs that are soluble in either volatile organic solvent or partially water-miscible solvent. Such solvents can be used as the dispersed phase of the emulsion. An organic solvent or mixture of solvents loaded with the drug is dispersed in the aqueous phase containing suitable surfactants with stirring to form an emulsion. The obtained emulsion was further homogenized by high pressure homogenization. After homogenization cycles the emulsion was diluted with water, homogenized by homogenizer to diffuse the organic solvent and convert the droplets into solid



particles. Since one particle is formed in each emulsion droplet, it is possible to control the particle size of the Nanosuspension by controlling the size of the emulsion optimizing the surfactant composition increases the intake of organic phase and ultimately the drug loading in the emulsion. Originally methanol, ethanol, ethyl acetate chloroform are used as a organic solvents.<sup>47-50</sup>

#### Advantages

- Use of specialized equipment is not necessary.
- Particle size can easily be controlled by controlling the size of the emulsion droplet.
- Ease of scale-up if formulation is optimized properly.

#### Disadvantages

- Drugs that are poorly soluble in both aqueous and organic media cannot be formulated by this technique.
- Safety concerns because of the use of hazardous solvents in the process.
- Need for diultrafiltration for purification of the drug Nanosuspension, which may render the process costly.
- High amount of surfactant/stabilizer is required as compared to the production techniques described earlier.<sup>47-50</sup>

#### Micro emulsion Template

This technique follows an organic solvent or mixture solvent loaded with the drug dispersed in an aqueous phase containing suitable surfactants to form an emulsion. The organic phase is then evaporated under reduced pressure to make drug particles precipitate instantaneously to form the Nanosuspension which is stabilized by surfactants. Another method makes use of partially water-miscible solvents such as butyl lactate, benzyl alcohol and triacetin as the dispersed phase instead of hazardous solvents.<sup>48-51</sup>

#### Advantages

- Use of specialized equipment is not necessary.
- Particle size can easily be controlled by controlling the size of the emulsion droplet.
- Ease of scale-up if formulation is optimized properly.

#### Disadvantages

- Drugs that are poorly soluble in both aqueous and organic media cannot be formulated by this technique.
- Need for diultrafiltration for purification of the drug Nanosuspension, which may render the process costly.
- High amount of surfactant/stabilizer is required as compared to the production techniques described earlier.

#### Supercritical Fluid Method

Supercritical fluid technology can be used to produce nanoparticles from drug solutions. The various methods

attempted are rapid expansion of supercritical solution process (RESS), supercritical anti-solvent process and precipitation with compressed anti-solvent process (PCA). The RESS involves expansion of the drug solution in supercritical fluid through a nozzle, which leads to loss of solvent power of the supercritical fluid resulting in precipitation of the drug as fine particles. Young *et al.* prepared cyclosporine nanoparticles in the size range of 400-700 nm using this process. In the PCA method, the drug solution is atomized into a chamber containing compressed CO<sub>2</sub>. As the solvent is removed, the solution gets supersaturated and thus precipitates as fine crystals. The supercritical anti-solvent process uses a supercritical fluid in which a drug is poorly soluble and a solvent for the drug that is also miscible with the supercritical fluid. The drug solution is injected into the supercritical fluid and the solvent gets extracted by the supercritical fluid and the drug solution gets supersaturated. The drug is then precipitated as fine crystals. Nanoparticles of griseofulvin, a drug with poor solubility, were prepared by Chattopadhyay *et al.* using this method.<sup>46-51</sup>

#### Disadvantages

- Use of hazardous solvents and use of high proportions of surfactants and stabilizers as compared with other techniques,
- Particle nucleation overgrowth due to transient high super saturation, which may also result in the development of an amorphous form or another undesired polymorph.

#### Melt emulsification method

In this method drug is dispersed in the aqueous solution of stabilizer and heated above the melting point of the drug and homogenized to give an emulsion. During this process, the sample holder was enwrapped with a heating tape fitted with temperature controller and the temperature of emulsion was maintained above the melting point of the drug. The emulsion was then cooled down either slowly to room temperature or on an ice-bath<sup>50,51</sup>

#### Advantage

Melt emulsification technique relative to the solvent diffusion method is total avoidance of organic solvents during the production process.

#### Dry Co-Grinding

Recently, Nanosuspensions can be obtained by dry milling techniques. Successful work in preparing stable Nanosuspensions using dry-grinding of poorly soluble drugs with soluble polymers and copolymers after dispersing in a liquid media has been reported. Many soluble polymers and co-polymers such as PVP, polyethylene glycol (PEG), hydroxypropyl methylcellulose (HPMC) and cyclodextrin derivatives have been used.<sup>51,52</sup>





## Formulation Consideration

### Stabilizer

The main function of a stabilizer is to wet the drug particles thoroughly, and to prevent ostwald's ripening and agglomeration of Nanosuspensions in order to yield a physically stable formulation by providing steric or ionic barrier. The type and amount of stabilize has a pronounced effect on the physical stability and in vivo behavior of Nanosuspension. Stabilizers that have been used so far are poloxomers, polysorbate, celluloses, povidones, and lecithins.

Lecithin is the stabilizer of choice if one intends to develop a parentally acceptable and autoclavable nanosuspension.<sup>52</sup>

### Organic Solvent

Organic solvents are used in the formulation of Nanosuspension if emulsions or micro emulsions are used as a template. The pharmaceutically acceptable less hazardous water miscible solvent, such as methanol, ethanol, chloroform, isopropanol, and partially water miscible solvents ethyl acetate, ethyl formate, butyl lactate, triacetin, propylene carbonate, benzyl alcohol, are preferent in the formulation over the conventional hazardous solvents, such as dichloromethane.<sup>52,53</sup>

### Co-Surfactants

The choice of co-surfactant is critical when using micro emulsions to formulate Nanosuspensions. Since co-surfactants can greatly influence phase behaviour, the effect of co-surfactant on uptake of the internal phase for selected micro emulsion composition and on drug loading should be investigated. Although the literature describes the use of bile salts and dipotassium glycerphosphate as co-surfactants, various solubilizers, such as Transcutol, glycofurol, ethanol and isopropanol, can be safely used as co-surfactants in the formulation of microemulsions.<sup>54</sup>

### Other additives

Nanosuspensions may contain additives such as buffers, salts, polyols, osmogent and cryoprotectant.

### Post-Production Processing

Post-production processing of Nanosuspensions becomes essential when the drug candidate is highly susceptible to hydrolytic cleavage or chemical degradation. Processing may also be required when the best possible stabilizer is not able to stabilize the Nanosuspension for a longer period of time or there are acceptability restrictions with respect to the desired route. Considering these aspects, techniques such as lyophilization or spray drying may be employed to produce a dry powder of nano-sized drug particles. Rational selection has to be made in these unit operations considering the drug properties and economic aspects. Generally, spray drying is more economical and convenient than lyophilization. The effect of post-production processing on the particle size of the

nanosuspension and moisture content of dried nanosized drug should be given due consideration.<sup>53,54</sup>

## Characterization of Nanosuspension<sup>1-54</sup>

### In-vitro evaluations

- Color, Odor, Taste
- Particle size distribution
- Particle charge (Zeta Potential)
- Crystal morphology
- Dissolution velocity and Saturation solubility
- Density
- pH Value
- Droplet Size
- Viscosity Measurement
- Stability of Nanosuspension

### In-vivo Biological Performance

### Evaluation for surface-modified Nanosuspension

- Surface hydrophilicity
- Adhesion properties
- Interaction with body proteins

### In-vitro evaluations

- **Color, Odor, Taste**

These characteristics are especially important in orally administered formulation. Variations in taste, especially of active constituents, can offered be attributed to changes in particle size, crystal habit and subsequent particle dissolution. Changes in color, odor and taste can also indicate chemical instability.

- **Particle Size Distribution**

Particle size distribution determines the physiochemical behavior of the formulation, such as saturation solubility, dissolution velocity, physical stability, etc. The particle size distribution can be determined by photon correlation spectroscopy (PCS), laser diffraction (LD) and coulter counter multisizer. The PCS method can measure particles in the size range of 3 nm to 3µm and the LD method has a measuring range of 0.05-80µm. The coulter counter multisizer gives the absolute number of particles, in contrast to the LD method, which gives only a relative size distribution. For IV use, particles should be less than 5µm, considering that the smallest size of the capillaries is 5-6µm and hence a higher particle size can lead to capillary blockade and embolism.

- **Zeta Potential**

Zeta potential is an indication of the stability of the suspension. For a stable suspension stabilized only by electrostatic repulsion, a minimum zeta potential of ±30 mV is required whereas in case of a combined electrostatic and steric stabilizer, a zeta potential of ±20 mV would be sufficient.



- **Crystal Morphology**

To characterize the polymorphic changes due to the impact of high-pressure homogenization in the crystalline structure of the drug, techniques like X-ray diffraction analysis in combination with differential scanning calorimetry or differential thermal analysis can be utilized. Nanosuspensions can undergo a change in the crystalline structure, which may be to an amorphous form or to other polymorphic forms because of high-pressure homogenization.

- **Dissolution Velocity and Saturation Solubility**

Nanosuspensions have an important advantage over other techniques, that it can increase the dissolution velocity as well as the saturation solubility. These two parameters should be determined in various physiological solutions. The assessment of saturation solubility and dissolution velocity helps in determining the *in vitro* behavior of the formulation. Böhm *et al.* reported an increase in the dissolution pressure as well as dissolution velocity with a reduction in the particle size to the nanometer range.<sup>17</sup> Size reduction leads to an increase in the dissolution pressure.

- **Density**

Specific gravity or density of the formulation is an important parameter. A decrease in density often indicates the presence of entrapped air within the structure of the formulation. Density measurements at a given temperature should be made using well mixed, uniform formulation; precision hydrometer facilitate such measurements.

- **pH Value**

The pH value of aqueous formulation should be taken at a given temperature and only after settling equilibrium has been reached, to minimize "pH drift" and electrode surface coating with suspended particles. Electrolyte should not be added to the external phase of the formulation to stabilize the pH.

- **Droplet Size**

The droplet size distribution of micro emulsion vesicles can be determined by either light scattering technique or electron microscopy. Dynamic light scattering spectrophotometer which uses a neon laser of wavelength 632 nm.

- **Viscosity Measurement**

The viscosity of lipid based formulations of several compositions can be measured at different shear rates at different temperatures using Brookfield type rotary viscometer. The sample room of the instrument must be maintained at 37°C by a thermo bath and the samples, for the measurement are to be immersed in it.

- **Stability of Nanosuspension**

The high surface energy of nanosized particles induces agglomeration of the drug crystals. The main function of the stabilizer is to wet the drug particles thoroughly to prevent Ostwald ripening and agglomeration of the Nanosuspension and form a physically stable formulation by providing a steric or an ionic barrier. Typical examples of stabilizers used in Nanosuspensions are cellulose, poloxamer, polysorbates, lecithin, polyoleate and povidones. Lecithin may be preferred in developing parenteral Nanosuspensions.

- **In-Vivo Biological Performance**

The establishment of an in-vitro/in-vivo correlation and the monitoring of the in-vivo performance of the drug is an essential part of the study, irrespective of the route and the delivery system employed. It is of the utmost importance in the case of intravenously injected Nanosuspensions since the in-vivo behavior of the drug depends on the organ distribution, which in turn depends on its surface properties, such as surface hydrophobicity and interactions with plasma proteins. In fact, the qualitative and quantitative composition of the protein absorption pattern observed after the intravenous injection of nanoparticles is recognized as the essential factor for organ distribution. Hence, suitable techniques have to be used in order to evaluate the surface properties and protein interactions to get an idea of in-vivo behavior. Techniques such as hydrophobic interaction chromatography can be used to determine surface hydrophobicity, whereas 2-D PAGE can be employed for the quantitative and qualitative measurement of protein adsorption after intravenous injection of drug nanosuspensions in animals.

## APPLICATIONS OF NANOSUSPENSIONS

### Oral

Oral drug delivery is the most widely preferred route of administration of drugs. But, some drugs possess the problem of limited bioavailability due to poor solubility and absorption which ultimately reduces its efficacy. In such cases, Nanosuspension can solve the problem as it helps in improving the dissolution rate and absorption due to increased surface area and enhanced adhesiveness. Nanosuspension can lead to increased mucoadhesion which can increase gastrointestinal transit time and lead to increased bioavailability. The enhancement in oral bioavailability can be attributed to increased surface area, saturation solubility and the adhesiveness of the drug Nanosuspension. Taste masking of particulate system is also easily possible.

### Parenteral

Nanosuspensions can be used to transform poorly soluble non-injectable drugs into a formulation suitable for intravenous administration. Although the production of Nanosuspension for parenteral use is critical, current developments in this technology have proved its utility as

injectable formulations. The methods used for preparation of Nanosuspension are now precisely controlled, and are able to produce uniform particles with better control over maximum particle size. Various research reports are available which emphasize the applicability of Nanosuspensions for parenteral administration.

### Ocular delivery

Nanosuspension can prove to be a boon for drugs that exhibit poor solubility in lachrymal fluids. Nanosuspensions represent an ideal approach for ocular delivery of hydrophobic drugs due to their inherent ability to improve saturation solubility of drugs. Kassem et al., have developed Nanosuspension delivery system for certain glucocorticoid drugs

### Pulmonary

Nanosuspensions can be advantageous for delivering drugs that exhibit poor solubility in pulmonary secretion. Currently available approaches for pulmonary delivery such as aerosols or dry powder inhalers possess certain disadvantages such as limited diffusion at required site, less residence time etc, which can be overcome by Nanosuspensions. Fluticasone and budesonide have been successfully formulated as Nanosuspension for pulmonary Delivery.

### Dermal

The nanocrystalline form possesses increased saturation solubility resulting in enhanced diffusion of the drug into the skin. Nanocrystals also exhibit various properties such as increased penetration into a membrane, enhanced permeation and bioadhesiveness which could be very useful for dermal application.

### Targeting

The uptake of drug nanoparticles depends on their particle size. By changing the surface properties of the nanoparticles, their *in vivo* behavior can be altered and can be used as targeted delivery system. The phagocytotic uptake of nanocrystals can be avoided by preparing stealth nanocrystals or by preparing smart crystals i.e. drug particles below particle size of 100nm, which can be used as a targeted drug delivery system. Due to method simplicity, development of nanosuspension is a commercially viable option for targeted delivery. Mucoadhesive nanosuspension was reported for targeting of *Cryptosporidium parvum*. The surface properties of particles such as surface hydrophobicity, charge, presence and concentration of certain functional groups determine its organ distribution. Thus, Tween 80 coated nanocrystals can be used for brain targeting. Atovaquone nanocrystals coated with Tween 80 were used to treat toxoplasmosis; the parasites could be efficiently eradicated in brain.

### Mucoadhesion of the Nanoparticles

Nanoparticles orally administered in the form of a suspension diffuse into the liquid media and rapidly encounter the mucosal surface. The particles are immobilized at the intestinal surface by an adhesion mechanism referred to as "bioadhesion." From this moment on, the concentrated suspension acts as a reservoir of particles and an adsorption process takes place very rapidly. The direct contact of the particles with the intestinal cells through a bioadhesive phase is the first step before particle absorption.

**Table 1:** Marketed Products

Product	Drug	Indication	Company
Triglide	Fenofibrate	Treatment of hypercholesterolemia	First horizon pharmaceutical
Tricor	Fenofibrate	Treatment of hypercholesterolemia	Abbott
Megace	Megestrol aceyate	Appetite stimulant	PARPharmaceutical
Rapamune	sirolimus	Immunosuppressant	Wyeth

### Future Prospects

Nanosuspension technology is a unique and novel approach to overcome drug problems such as poor bioavailability that are related with the delivery of hydrophobic drugs, including those that are poorly soluble in aqueous as well as organic media. Production methods like media milling and high-pressure homogenization have been successfully employed for large scale production of Nanosuspensions. Nanosuspension technology can be combined with traditional dosage forms: tablets, capsules, pellets, and can be used for parenteral products. To take advantage of Nanosuspension drug delivery, simple formation technologies and variety applications, Nanosuspensions will continue to be of interest as oral formulations and non-oral administration develop in the future. In consideration to data available Nanosuspensions can be considered as renaissance in formulation technologies for coming years.

### CONCLUSION

Nanosuspension solved poor bioavailability problem of hydrophobic drugs and drugs which are poorly soluble in aqueous and organic solutions. Production techniques such as media milling and high pressure homogenizer are used for large scale production of Nanosuspensions. Nanosuspensions can be administered through oral, parenteral, pulmonary, ocular and topical routes. Since nanotechnology is simple, less requirements of excipients, increased dissolution velocity and saturation solubility many poor bioavailability drugs are formulated in Nanosuspension form.

## REFERENCES

- Katteboinaa S, Drug nanocrystals: A novel formulation approach for poorly Soluble drugs, International journal of pharmtech research, 1(3), 2009, 682-694.
- Dineshkumar B, Nanosuspension Technology in Drug Delivery System, Nanoscience and Nanotechnology: An International Journal, 3(1), 2013, 1-3.
- Patel AP, A review on drug nanocrystal a carrier free drug delivery, IJRAP, 2(2), 2011, 448-458.
- Dhiman S, Nanosuspension: a recent approach for nano drug delivery system, International journal of current pharmaceutical research, 3, 2011, 96-101.
- Maravajhala V, Papishetty S, Bandlapalli S, Nanotechnology in development of drug delivery system. International Journal of Pharmaceutical Science and Research, 3(1), 2012, 84-96.
- Patel BP, A Review On Techniques Which Are Useful For Solubility Enhancement Of Poorly Water Soluble Drugs, International Journal For Research In Management And Pharmacy, 1, 2012, 56-70.
- Shukla M, Enhanced Solubility Study Of Glipizide Using Different Solubilization Techniques, International Journal Of Pharmacy and Pharmaceutical Sciences, 2, 2010, 46-48.
- Chaudhary A, Enhancement of solubilization and bioavailability of poorly soluble drugs by physical and chemical modifications: A recent review, Journal of Advanced Pharmacy Education & Research, 2 (1), 2012, 32-67.
- Kapadiya N, Hydrotropy: A Promising Tool for Solubility Enhancement: A Review. International Journal of Drug Development & Research, 3, 2011, 26-33.
- Thorat YS, Solubility Enhancement Techniques: A Review On Conventional And Novel Approaches, IJPSR, 2(10), 2011, 2501-2513.
- Sharma D, Solubility Enhancement – Eminent Role in Poorly Soluble Drugs, "Research J. Pharm. and Tech", 2(2), 2009, 220-224.
- Jain S, Solubility Enhancement By Solvent Deposition Technique: An Overview, Asian Journal Of Pharmaceutical And Clinical Research, 5(4), 2012, 15-19.
- N.A.M.Deecaraman, C.Rani, Mohanraj KP, Kumar KV, preparation and solid state characterization of atorvastatin nanosuspensions for enhanced solubility and dissolution, International Journal of PharmTech Research, 1, 2009, 1725-1730.
- Patel DJ, Patelj K, Pandya VM, 3rishad R. Jivani RR, Patel RD, Optimization of Formulation Parameters On Famotidine Nanosuspension Using Factorial Design And The Desirability Function, International Journal of PharmTech Research, 2, 2010, 155-161.
- Patil MS, Preparation And Optimization of Simvastatin Nanoparticle For Solubility Enhancement And In- Vivo Study, International Journal of Pharma Research and Development – Online, 2, 2011, 219-226.
- Wei Li, Preparation and *in vitro/in vivo* evaluation of revaprazan hydrochloride nanosuspension, International Journal of Pharmaceutics, 408, 2011, 157-162.
- Jorvekar.P, Pathak AA, Chaudhari PD, Formulation Development of Aceclofenac Loaded Nanosuspension by Three Square (3<sup>2</sup>) Factorial Design, International Journal Of Pharmaceutical Sciences and Nanotechnology, 4, 2012, 1575-1582.
- Banavath H. Sivarama RK, Tahir A, Sajid A, Pattnaik G, Nanosuspension: an attempt to enhance bioavailability of poorly soluble drugs, International Journal of Pharmaceutical Science and Research, 1(9), 2010, 1-11.
- Shegokar R, Müller RH, Nanocrystals: Industrially feasible multifunctional formulation technology for poorly soluble actives, International Journal of Pharmaceutics, 399, 2010, 129–139.
- Chingunpituk J, Nanosuspension Technology for Drug Delivery, Walailak J Sci & Tech, 4(2), 2007, 139-153.
- Patravale B, Abhijit AD, Kulkarni RM, Nanosuspensions: a promising drug delivery strategy, Journal of Pharmacy and Pharmacology, 56, 2004, 827–840.
- Prasanna L, Nanosuspension Technology: A Review, International Journal of Pharmacy and Pharmaceutical Sciences, 2( 4), 2010, 35-40.
- Xiaohui P, Jin S, Mo L, Zhonggui H, Formulation of Nanosuspensions as a New Approach for the Delivery of Poorly Soluble Drugs, Current Nanoscience, 5, 2009, 417-427.
- Mohanty S, Role of Nanoparticles in Drug Delivery System, International Journal of Research in Pharmaceutical and Biomedical Sciences, 1 (2), 2010, 41-66.
- Ch.P, A Review On Nanosuspensions In Drug Delivery, International Journal Of Pharma and Bio Sciences, 2, 2011, 549-558.
- Nagare SK, A review on Nanosuspension: An innovative acceptable approach in novel delivery system, Universal Journal of Pharmacy, 1(1), 2012, 19-31.
- Debjit B, Nanosuspension -A Novel Approaches In Drug Delivery System, The Pharma Innovation – Journal, 1(12), 2012, 50-63.
- Kamble VA, Nanosuspension A Novel Drug Delivery System, International Journal of Pharma And Bio Sciences, 1, 2010, 352-360.
- Soni S, Nanosuspension: An Approach to Enhance Solubility of Drugs, IJPI's Journal of Pharmaceutics and Cosmetology, 2(9), 2012, 50-63.
- Wagh KS, Patil SK, Akarte AK, Baviskar DT, Nanosuspension - A New Approach of Bioavailability Enhancement, International Journal of Pharmaceutical Sciences Review And Research, 8, 2011, 61-65.
- Patil SA, Rane BR, Bakliwal SR, Pawar SP, Nanosuspension: At A Glance, International Journal Of Pharmaceutical Science, 3(1), 2011, 947-960.
- Bansal.S, Bansal M, Kumria R, Nanocrystals: Current Strategies and Trends, International Journal of Research in Pharmaceutical and Biomedical Sciences, 3 (1), 2012, 406-419.
- Cornelia MK, Muller RH, Drug nanocrystals of poorly soluble drugs produced by high pressure homogenization,





- European Journal of Pharmaceutics and Biopharmaceutics, 62, 2006, 3–16.
34. Pintu KD, Nanosuspensions: Potent vehicles for drug delivery and bioavailability enhancement of lipophilic drugs, *Journal of Pharmacy Research*, 5(3), 2012, 1548-1554.
  35. Prasanta D, Nanotechnology For The Delivery of Poorly Water Soluble Drugs, *The Global Journal Of Pharmaceutical Research*, 1(3), 2012, 225-250.
  36. Patel M, Nanosuspension: A Novel Approach For Drug Delivery System, *JPSBR*, 1, 2011, 1-10.
  37. Shelke PV, A Review On Formulation And Evaluation of Nanosuspension, *International Journal of Universal Pharmacy And Life Sciences*, 2(3), 2012, 516-524.
  38. Venkatesh T, Nanosuspensions: Ideal Approach for the Drug Delivery of Poorly Water Soluble Drugs, *Der Pharmacia Lettre*, 3(2), 2011, 203-213.
  39. Yadav GV, Nanosuspension: A Promising Drug Delivery System, *Pharmacophore*, 3(5), 2012, 217-243.
  40. Pandey S, Nanosuspension: Formulation, Characterization and Evaluation, *International Journal of Pharma and Bio Sciences*, 1(2), 2010, 1-10.
  41. Toshi C, A Review on Nanosuspensions promising Drug Delivery Strategy, *Current Pharma Research*, 3(1), 2012, 764-776.
  42. Ezeddin K, Nanodispersions Platform for Solubility Improvement, *International Journal of Research in Pharmaceutical and Biomedical Sciences*, 4 (2), 2013, 636-643.
  43. Kumar GP, Nanosuspensions: The Solution to Deliver Hydrophobic Drugs, *International Journal of Drug Delivery*, 3, 2011, 546-557.
  44. Kumar BS, Review Article Increasing Possibilities of Nanosuspension, *Journal of Nanotechnology*, 2013, 1-12.
  45. Battula SR, Nano Fabricated Drug Delivery Devises, *International Journal of Pharmacy & Technology*, 4 (1), 2012, 1974-1986.
  46. Venkatesh T, Nanosuspensions: Ideal Approach for the Drug Delivery of Poorly Water Soluble Drugs, *Der Pharmacia Lettre*, 3(2), 2011, 203-213.
  47. Paun JS, Nanosuspension: An Emerging Trend for Bioavailability Enhancement of Poorly Soluble Drugs, *Asian J. Pharm. Tech*, 2(4), 2012, 157-168.
  48. Vaghela A, Nanosuspension Technology, *International Journal of Universal Pharmacy and Life Sciences*, 2(2), 2012, 306-317.
  49. Bhargavi A, Technical Review of Nanosuspensions, *International Journal of Pharmacy & Technology*, 3(3), 2011, 1503-1511.
  50. Verma KAK, Nanosuspensions: Advantages and Disadvantages, *Indian Journal of Novel Drug Delivery*, 4(3), 2012, 179-188.
  51. Srinivasa RK, an Overview of Statins as Hypolipidemic Drugs, *International Journal of Pharmaceutical Sciences and Drug Research*, 3(3), 2011, 178-183.
  52. Nagaraju P, Nanosuspension: A Promising Drug Delivery System, *International Journal of Pharmaceutical Sciences and Nanotechnology*, 2(4), 2010, 679-684.
  53. Koteswara KB, Nanosuspension: A Novel Drug Delivery Approach, *IJRAP*, 2(1), 2011, 162-165.
  54. Mudgil M, Gupta N, Nagpal M, Pawar P, Nanotechnology: A New Approach For Ocular Drug Delivery System, *International Journal Of Pharmacy And Pharmaceutical Sciences*, 4(2), 2012, 105-112.

**Source of Support:** Nil, **Conflict of Interest:** None.