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A REVIEW ON NANOSPONGES-NOVEL APPROACH OF TARGETED DRUG DELIVERY

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ABSTRACT

The aim of Novel Drug Delivery System is to provide a therapeutic amount of drug to the appropriate site in the body to accomplish promptly and then maintain the desired drug concentration. A number of novel drug delivery system has emerged encompassing various routes of administration, to achieve controlled and targeted drug delivery. Encapsulation of the drug in vesicular structure is one such system, which can be predicted to prolong the existence of the drug in systemic circulation and reduce the toxicity if selective uptake can be achieved. Consequently a number of vesicular drug delivery system such as liposomes, niosomes, transfersomes and pharmacosomes were developed. Nanosponge play vital role in targeting drugs delivery in a controlled manner. This sponge can circulate around the body until interact with specific target site and stick on surface and releasing drug in controlled manner both lipophilic and hydrophilic drugs are incorporated in nanosponge. Important characteristics of these sponges are their solubility in aqueous from and suitable for the drugs with poor solubility. This review is focusing on the preparation, advantages, characteristics and applications of nanosponges in the field of drug delivery.

KEYWORDS: Nanosponges, synthesis, preparation, evaluation, β-cyclodextrins, poor soluble drugs.

INTRODUCTION

Nanosponges are nanosized drug carriers with a three-dimensional structure created by crosslinking polymers. They have the advantage of being able to hold a wide range of drugs

of various sizes. Nanosponges come in a variety of shapes and sizes. They are distinguished by the research method used, the type of polymer used, and the type of drug they may contain. Nanosponges are superior to other delivery systems because they can provide a controlled drug release pattern with targeted drug delivery. The period of action, as well as the drug's residence time, may be regulated. Since it is made of biodegradable materials, it has a low toxicity and is safe to use. The efficiency of drug encapsulation is determined by the size of the drug molecule and the amount of void space available. Cancer, enzyme and biocatalyst carrier, oxygen delivery, solubility enhancement, enzyme immobilization, and poison absorbent are some of the applications for nanosponges.[1]

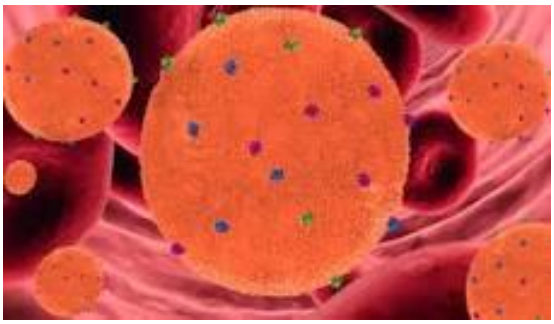

Fig. No. 1: Shows the nanosponge representation.

TYPES OF NANOSPONGES[2]

There are many types of NS that are available and can be designed and formulated depending on the polymer added, its concentration, and the method of preparation used accordingly. The most common types of NS which are prepared and have been diversely used are beta CD-based NS. The formulation aspect for beta-CD NS is a relatively simple process and there are relatively multiple modifications that are possible. The types of Nanosponges shows in Table 1.

Table 1: Types of Nanosponges.

Types of Nanosponges
Titanium based nanosponges,
Carbon coated metallic nanosponges,
Beta – cyclo dextrin nanosponges,
Hyper cross linked nanosponges,
Silicon nanosponges particles.

Cyclodextrin Nanosponges

DeQuan Li and Min Ma in 1998 were the first who used the term cyclodextrin nanosponges (CDNS) to indicate a cross-linked β-cyclodextrin with organic diisocyanates leading to the

formation of an insoluble network which indicate high inclusion constant with various organic pollutants. CDNS are suggested as a new nanosized drug delivery system with crosslinked polymers of cyclodextrin nanostructure within a three-dimensional network. CD polymer can form porous insoluble nanoparticles with crystalline or amorphous structure and spherical shape with tunable polarity anddimension by changing the crosslinker and degree of cross linking.

There are three types of CD: Alpha-cyclodextrin (α) Betacyclodextrin (β) Gamma-cyclodextrin(γ) Delta cyclodextrin(δ), the 3 natural CDs, α-, β- and γ- CDs differ in their ring size and solubility.

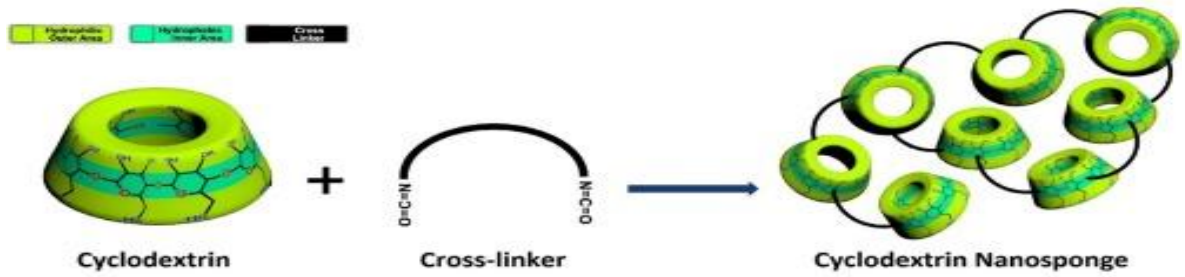

Fig. No. 2: Cyclodextrin Nanosponges.

Cyclodextrins have been mainly considered for pharmaceutical field because

1. They are semi-natural products, produced from renewable natural material of starch, by relatively simple enzymatic conversion.
2. They are produced in thousands of tons per year by environmental friendly techniques.
3. Any of their toxic effect is of secondary character and can be eliminated by selecting the appropriate Cyclodextrin type or derivatives or mode of application.

The natural α- CD and β- CD, unlike γ- CD are not hydrolyzed by human salivary enzyme and pancreatic amylases; though all three are subjected to fermentation by the intestinal micro flora. At moderate oral doses hydrophilic CDs are non toxic. The naturally occurring CD and its derivatives are used in oral and topical formulations, but only α- cyclodextrin and the hydrophilic derivatives of β- and γ-cyclodextrin can be used in parenteral formulations. The γ-cyclodextrin forms visible aggregates in aqueous solution and is not well suited for parenteral formulations.

CDNS are a new class of amorphous cross-linked polymers obtained by reacting CD with a suitable poly-functional agent such as carbonyldiimidazole (CDI) or pyromellitic anhydride.

The reaction products turned out to be highly cross-linked, nanoporous polymers showing interesting inclusion/release properties. The presence of the lipophilic cavities of CD units and hydrophilic channels within the porous structure provides the CDNS with the capability of encapsulating a large variety of compounds. Moreover, the type and the amount of crosslinking agent may dramatically regulate the various parameters like the swelling index and hydrophilicity/ hydrophobicity of the final product. These properties make CDNS highly attractive for several applications in biocatalysis, agriculture and environmental protection and drug-delivery.

CHARACTERISTIC FEATURES OF NANOSPONGES[3]

The characteristics features of Nanosponges were shows in Table 2.

Table 2: Characteristic Features of Nanosponges.[3]

Characteristic features of Nanosponges[3]
Nanosponges provide a range of dimensions (1 µm or less) with tunable polarity of the cavities. Nanosponges of specific size can be synthesized by changing the cross linker to polymer ratio. They exhibit para crystalline or crystalline forms, depending on the process conditions. Drug loading capacity depends on the degree of crystallization. Various drug loading capacities can be shown by paracrystalline nanosponges. They are nontoxic, porous particles, insoluble in most organic solvents and stable up to 300°C. They are stable at the pH range of 1-11. They form clear and opalescent suspension in water.

ADVANTAGES[4]

These formulations are stable over range of pH 1 to 11. These formulations are stable at higher temperatures. These formulations are compatible with most vehicles and ingredients. These are self-sterilizing as their average pore size is 0.25µm where bacteria cannot penetrate. These formulations are free flowing and can be cost effective. This technology offers entrapment of ingredients and reduced side effects, improved stability, increased elegance, and enhanced formulation flexibility. Nanosponges are non-irritating, non-mutagenic, non allergenic, and non-toxic. Extended release action up to 12 hrs can be attained. Allows incorporation of immiscible liquid, Improves material processing as liquid can be converted to powders. Easy scale up for commercial production.

DISADVANTAGES

Nanosponges have ability to include only small molecules. Nanosponges could be either para crystalline or in crystalline form. The loading capacity of nanosponges depends mainly on degree of crystallization. Para crystalline nanosponges can show different loading capacities Components used for the synthesis of nanosponges,[4] shows in Table 3.

Polymer	Co polymer	Cross linker	Polar solvents
Hyper Crosslinked Polystyrene Cyclodextrin	Poly (Valerolactone allyl Valerolactone)	Carbonyl diimidazole	• Ethanol
Acrylic Polymer	Poly (Valerolactone allyl Valerolactone oxypanedione)	Carboxylic acid di anhydrides	Di-methylacetamide
Methyl β-Cyclodextrin	• Ethyl cellulose	• Diarylcarbonates	Dimethylformamide
Hydroxy propyl β-cyclodextrin	Polyvinyl alcohol	Dichloromethane	
Poly-Valerolactone		Di-isocyanates	
Eudragit RS100		Glutaraldehyde	
		Pyromellitic anhydride	

Polymer

Type of polymer used can influence the formation as well as the performance of nanosponges. For complexation, the cavity size of nanosponge should be suitable to accommodate a dug molecule of particular size. The ability of the polymer to be cross linked depends on the functional groups and active groups to be substituted. The selection of polymer depends on the required release and the drug to be enclosed.

Co-polymers

Poly (Valerolactoneallylvalerolactone), Poly(Valerolactoneallylvalerolactone oxepanedione), ethyl cellulose, polyvinyl alcohol.

Cross-linkers

Selection of cross linkers depends on thestructure of polymer and the drug to be formulated.

Drug substances

Drug molecule to be formulated as nanosponges should have certain characteristics- Molecular weight between 100 and 400 Daltons. Drug molecule consists of less than 5

condensed rings. Solubility in water is less than 10mg/ml. Melting point of the substance is below 250°C.

Table 6: BCS Classification System of Drugs.

CATEGORY/ CLASS	EXAMPLES
Antihypertensive drugs	Felodipine, Nicardipine, Nifidipine, Nislodipine
Antiarrhythmic agents	Amiodarone hydrochloride
Antibiotics	Azithromycin, Ciprofloxacin, Erythromycin, Ofloxocin
Antifungal agents	Econozole nitrate, Griseofulvin, itraconazole, Ketoconazaole, Lansoprazole
Antiepileptic drugs	Phenytoin
Gastroprokinetic agents	Cisapride
Steroids	Danazol, Dexamethazone
Antiulcer drugs	Lansoprazole, Omeprazole
Immunosupressants	Cyclosporine, Sirolimus, Tacrolimus
Anti histaminics	Terfenadine
Antianxiety drugs	Lorazepam
Antioxidants	Resveratrol
Diuretics	Chlorthalidone, Spirinolactone

METHOD OF PREAPARATION OF NANOSPONGES

Solvent method[5]

Suitable solvents, like dimethyl formamide and dimethylsulfoxide which are polar aprotic solvents, were used in the process. To this, polymer was added and properly blended. The cross linker/polymer ratio of 8:2 is ideally used into which the above mixture was added. The mixture got from the above mixing, was then left to react for 48 hours and in a temperature range of 10°C and up to solvent's reflux temperature. On completion of the reaction, the solution was cooled until it reached the room temperature. Excess amount of bi-distilled water was added to obtain the product from the above-cooled solution and the product was recovered under vacuum filtration.

Ultrasound-assisted method[6]

The ultrasound-assisted method of synthesis utilizes polymer ultrasonics junction. Cross linking is got without using any solvent, and polymer cross linking occurs due to ultrasonic waves. In a flask, polymer and cross linker were combined at a reasonable molar ratio. During the ultrasonication process, ultrasound bath was used to place the flask, at a temperature of 90 °C and for a time period of 5 h. The temperature of the collected mixture was reduced after sonication, and the product was split harshly and cleaned to extract un reacted polymer and reagents with an excess volume of water. The washed solid was purified

with ethyl alcohol by Soxhlet extraction. The filtered NSs acquired were vacuum dried and processed correctly until further loading of drugs.

Melt method[7]

The cross linker and the polymer are melted together in the melting process. All the ingredients were finely homogenized. NSs were collected by washing the acquire product repeatedly with a suitable liquid. Cleaning the product, extracts the waste polymer and reagents which are un reacted and divides the product into the form of NSs. Such blank NSs were further exposed to the encapsulating of narcotics.

Bubble electro spinning [8]

A conventional and typical electro spinning configuration consists primarily of a syringe, syringe pump, as defined in many literatures, a high-voltage power, and a grounded collector. But one of the major limitations that limits their applications is the amount of output of nano fibers. In bubble electro spinning, polyvinyl alcohol can also be used as polymer. By addition of distilled water into it, the solution of polymer (10%) was organized, which was then moved at 80–90 °C for 2 h to obtain a one-phase mixture. It was then left to achieve at room temperature with the polymer solution and then used to prepare nanoporous fibers.

Synthesis by the use of microwave radiation[9]

This is the simple technique of microwave irradiation synthesis of CD NSs that significantly decreases the reaction time. These NSs have higher crystallinity levels. Synthesis of NSs by microwave radiation showed a fourfold decrease in reaction time compared to traditional heating methods and also produced homogeneous particle size distribution with uniform crystallinity. Singireddy et al. performed an experiment to ascertain beneficial effects of microwave-assisted heating in comparison to conventional heating during the synthesis of CD-based NSs. In the research, the outcomes suggested that NSs synthesized by microwave-assisted synthesis has doubled the drug holding capacity for the model drug. The results of high resolution-transmission electron microscopy (HRTEM) displayed that the NSs obtained by microwave synthesis were highly crystalline, and showed increased degree of complexity along with narrow size distribution. The reaction time was greatly decreased for all reactions and the reaction products were improved under micro wave assisted heating conditions. The benefit by means of synthesis using microwave irradiation is that it supplies straight energy to the targeted molecules and hence energy can be provided in precise form. The energy is not

lost on heating the walls of the container or the liquid adjacent the reactant molecules and hence the full effect is seen in reaction progress towards completion.

Preparation of NSs from hypercrosslinked β-cyclodextrin[10]

Arranged from β-CDs, their function as transporters for drug conveyance is carried out as nanosporous materials. Because of this 3-D structures, which could be a typically circular assembly about the extent of a protein with directs and openings in the inner portion, they are framed. For example, di-isocyanates, diaryl carbonates, carbonyl di imidazoles, and so on, react to CD with a crosslinker. The measurement of wipes is regulated by porosity, surface thickness of charge for the relation to different atoms. NSs are mixed depending on the cross linker used in an impartial or acidic structure. They consist of solid particles and in the crystalline structure they have modified. Limit of NSs to demonstrate the tranquility and dissolvability of distinctive structures. They are used to improve fluid dissolvability of drugs with insufficient water solvents.

Emulsion solvent diffusion method[11]

Two steps are used in this technique to vary the level of natural and aqueous (ethyl cellulose and polyvinyl liquor). In dichloromethane (20 ml) and an unmistakable measure of polyvinyl liquor added to 150 ml of fluid ceaseless process, the scattered stage with ethyl cellulose and moiety is dissolved. At this point, for 2 hours at 1000 rpm, the blend is thoroughly blended. The required NSs were collected by the filtration method and held for drying in an oven at 40 °C for 24 h. Dried NSs have been put away in desiccators and the evacuation of remaining solvents is assured.

Quasi emulsion solvent method[12]

The NSs were arranged in different sums using the polymer. Using Eudragit RS 100, the inner stage is prepared and added to a fair dissolvable stage. The drug used produced a response and broke down at 35 °C under ultrasonication.[57] As an emulsifying operator, this internal process used in the outside phase containing polyvinyl alcohol goes around. At room temperature, the blend is blended at 1000–2000 rpm for 3 h and dried for 12 h in an air-warmed oven at 40 °C.

Factors influencing the formation of Nanosponge[13,14,15]

Polymer and Cross-linkers

The type of polymer used can influence the formulation as well as performance of nanosponges. Efficient cross-linker converts molecular nanocavities into 3-dimensional nanoporous structure.

- Hydrophilic nanosponge- they are formed by using epichlorohydrin as cross linker. Hydrophilic nanosponges modify the rate of drug release and enhance drug absorption across biological barriers, serving as a potent drug carrier even in immediate release formulation.
- Hydrophobic nanosponges can be synthesized by using diphenyl carbonate, pyromellitic anhydride, diisocynates, and carbonyldiimidazole as crosslinker. They serve as sustained release carriers for water soluble drugs including peptide and protein drugs.

Types of Drug and Medium Used for Interaction

The drug molecule used in nanosponge formulation should have following characteristics. Molecular weight between 100 and 400 Daltons. Drug molecule consists of less than 5 condensed rings. Solubility in water is less than 10mg/ml. Melting point of the substance is below 250°C.

Complexation Temperature

The stability constant of a complex is dependent on temperature changes. The stability constant and temperature rise are inversely correlated. At increased temperature, the magnitude of apparent stability constant decreases due to reduction in drug/nanosponge interaction forces. Hence, a thorough control over the temperature should be maintained when nanosponges are prepared.

Degree of Substitution

The number, type and position of the substituent on the polymeric molecule affect the complexation ability of nanosponges. The type of substitution is important because β-CD derivatives are available in various forms differing in functional groups present on the surface of the cyclodextrin derivative. When complexed together with the help of a cross linker, different functional groups yield different types of complexed material (β-CD nanosponges, CD-carbamate nanosponges, CD-carbonate nanosponges, etc.) There is a direct correlation between the number of substitutions present and the degree of cross linking, higher the number of substituent, the greater is the probability of undergoing higher cross linking. Higher degree of cross linking will yield highly porous nanosponges due to more

interconnections between polymers forming a mesh type network. The position of substitution depends on the production conditions. A change in the production process will yield materials with different physicochemical properties due to occupancy of some different position by the functional group on the parent compound.

Mechanism of drug release

The nanosponges have an open structure (in the surrounding of nanosponges they do not have any continuous membrane), the active substance is added to the vehicle in an encapsulated form. The encapsulated active substance is able to move freely from the particles into the vehicle untill in an encapsulate form. The encapsulated active substance is able to move freely from the particles into the vehicle until the vehicle gets saturated and the equilibrium is obtained. As soon as the product is applied on the skin, the vehicle containing the active ingredient gets unsaturated causing a disturbance in the equilibrium. Thus the flow of active substances from nanosponges particles into the vehicles starts to epidermis until the vehicle is either absorbed or dried. Even after the retention of the nanosponge particles on the surface of skin i.e. the stratum corneum, the release of active substance continues to skin for a long period of time.

Characterization and evaluation of Nanosponges

Particle size and polydispersity index

The particle size can be determined by dynamic light scattering using 90 Plus particle sizer equipped with MAS OPTION particle sizing software or laser light diffractometry or Malvern Zeta sizer. From this, the mean diameter and polydispersity index can be determined values of polydispersity index are given in Table 5.

Polydispersity Index	Type of Dispersion
0-0.05	Monodisperse standard
0.05-.08	Nearly monodisperse
0.08-0.7	Mid range polydispersity
>0.7	Very polydisperse

Resiliency

Resiliency (viscoelastic properties) of sponges can be modified to produce beadlets that are softer or firmer according to the needs of the final formulation. Increased crosslinking tends to slow down the rate of release. Hence resiliency of sponges will be studied and optimized as per the requirement by considering release as a function of cross-linking with time.

X-ray diffractometry and single crystal X-ray structure analysis

X-ray diffractiometry can be used to detect inclusion complexation in the solid state. When the drug molecule is liquid it does not shown diffraction of their own, then the diffraction pattern of newly formed substance clearly differs from that of uncomplexed nanosponges. The difference of diffraction pattern indicates the inclusion complex formation. When drug substance is solid in nature a comparison has to be made between diffractograms of the assumed complex and that of mixture of drug with polymer molecules. The inclusion complex formation of drug with nanosponges changes the diffraction patterns and also changes the crystalline nature of drug. Sharpening of the existing peaks and appearance of few new peaks leads to formation of inclusion complex.

Microscopy studies

Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) can be used to study the microscopic aspects of the drug, nanosponges and the product (drug/nanosponge complex). The difference in crystallization state of the raw materials and the product seen under electron microscope indicates the formation of the inclusion complexes.

Drug release kinetics

To investigate the mechanism of drug release from the Nanosponge the release data was analysed using Zero order, First order, and Higuchi, Korsemeyer-Peppas, Hixon Crowell, Kopcha and Makoid Banakar models. The data can be analysed using graph padprism software. The software estimates the parameters of a non-linear function that provides the closest fit between experimental observations and non- linear function.

Thermoanalytical methods

Thermo analytical methods determine whether the drug substance undergoes some changes before the thermal degradation of the nanosponge. The change of the drug substance may be melting, evaporation, decomposition, oxidation or polymorphic transition. The change of the drug substance indicates the complex formation. The thermogram obtained by differential thermal analysis and differential scanning calorimetry can be observed for broadening, shifting and appearance of new peaks or disappearance of certain peaks. Changes in the weight loss also can provide supporting evidence for the formation of inclusion complexes.

Infra-Red spectroscopy

The interaction between nanosponges and the drug molecules in the solid state can be detected by Infra-Red spectroscopy. Upon complex formation the nanosponges bands changes. If the fraction of the guest molecules encapsulated in the complex is less than 25% bands which could be assigned to the included part of the guest molecules are easily masked by the bands of the spectrum of nanosponges. Infra-red spectroscopy is applicable to the drugs having some characteristic bands such as carbonyl or sulfonyl groups. This spectral study reveals information regarding the involvement of hydrogen in various functional groups. This generally shifts the absorbance bands to the lower frequency, increases the intensity and widens the band caused by stretching vibration of the group involved in the formation of the hydrogen bonds. Hydrogen bond at the hydroxyl group causes the largest shift of the stretching vibration band.

Thin Layer Chromatography

In Thin Layer Chromatography, the Rf values of a drug molecule diminish to considerable extent and this helps in identifying the complex formation between the drug and nanosponge.

Loading efficiency and production yield

The loading efficiency (%) of the nanosponges can be calculated according to the following equation.

Loading Efficiency = Actual drug content in NS÷ Theoretical drug content × 100

The production yield of the nanosponges can be calculated by following equation after determining accurate initial weight of the raw materials and final weight of the nanosponge obtained.

Production yield (PY) = Practical mass of NS ÷ Theoretical mass (polymer+Drug) × 100

Solubility studies

Higuchi and Connors have described an approach to study inclusion complexation as the phase solubility method which examines the solubility of drug in nanosponge. Phase solubility diagrams indicate the degree of complexation. In this method Erlenmeyer flask was used. The drug containing an aqueous solution of various percentages of nanosponges is added to the flask. The Erlenmeyer flask was stirred on a mechanical shaker at room temperature till it reaches a steady state, the suspension was filtered by centrifugation using a

3000 Dalton molecular filter (MICRON YN 30, Millipore Corporation, Bedford MA 1730 U.S.A).The solution was analyzed and the drug concentration is determined by high performance liquid chromatography.

Zeta potential

Zeta potential is used for the measurement of surface charge by using additional electrode in particle size equipment. In this process nanosponges containing samples were taken and diluted with 0.1mol/l KCl and placed in electrophoretic cell for an application of 15V/cm of electric field. From this the mean hydrodynamic diameter and poly dispersity index were determined after averaging of the total measurement.

Dissolution test

Dissolution profile of nanosponges can be studied by use of dissolution apparatus USP XXIII with a modified basket consisted of 5m stainless steel mesh, speed of the rotation is 150 rpm. The dissolution medium is selected while considering solubility of actives to ensure sink conditions. Samples from the dissolution medium can be analyzed by suitable analytical method.

Applications of Nanosponges[16]

Nanosponges have a wide range of applications in the pharmaceutical field, because of its biocompatibility and versatility. In the pharmaceutical field industry, nanosponges can be used as an excipient for the formulation of tablets, capsules, granules, pellets, suspensions, solid dispersions and topical dosage forms. Nanosponges can accommodate both lipophilic and hydrophilic drug molecules, basically, those drugs substances which belong to the biopharmaceutical classification system (BCS- class II)as well as the poorly water-soluble drug. Shows in table in Table 6.

Solubility enhancement

Nanosponges can improve the wetting and solubility of molecules with very poor solubility in water. The drugs can be molecularly dispersed within the nanosponge structure and then released as molecules, avoiding the dissolution step. Consequently, the apparent solubility of the drug can be increased. Many formulation and bioavailability problems can be solved by enhancing the solubility and dissolution rate of a substance, and nanosponges can greatly enhance the drug solubility.

Nanosponges for drug delivery

The nanosponges are solid in nature and can be formulated as Oral, Parenteral, Topical or Inhalation dosage forms. For the oral administration, the complexes may be dispersed in a matrix of excipients, diluents, lubricants and anti caking agents suitable for the preparation of capsules or tablets. For the parenteral administration the complex may be simply carried in sterile water, saline or other aqueous solutions. For topical administration they can be effectively incorporated into topical hydrogel.

Topical agents

Nanosponge delivery system is a unique technology for the controlled release of topical agents of prolonged drug release and retention of drug form on skin. Local anaesthetics, antifungal and antibiotics are among the category of the drugs that can be easily formulated as topical nanosponges. Rashes or more serious side effects can occur when active ingredients penetrate the skin. In contrast, this technology allows an even and sustained rate of release, reducing irritation while maintaining efficiency. A wide variety of substances can be incorporated into a formulated product such as gel, lotion, cream, ointment, liquid, or powder.

Nanosponges as a carrier for biocatalysts and in the delivery and release of enzymes, proteins, vaccines and antibodies

A number of systems for carrying enzymes and proteins have been developed, such as nano and microparticles, liposomes and hydrogels. Carriage in a particular system can protect proteins from breakdown, modify their pharmacokinetics and improve their stability *in-vivo.* Now, it has been found that Cyclodextrin based nanosponges are particularly suitable carrier to adsorb proteins, enzymes, antibodies and macromolecules. In particular when enzymes are used, it is possible to maintain their activity, efficiency, prolong their operation and extends the pH and temperature range of activity and allows the conduct of continuous flow processes.

Moreover, proteins and other macromolecules can be carried by adsorbing or encapsulating them in cyclodextrin nanosponges.

Nanosponges as a carrier for delivery of gases

Gases play an important role in medicine, either for diagnostic or treatment purposes. The deficiency of adequate oxygen supply, named hypoxia, is related to various pathologies, from

inflammation to cancer. It is sometime difficult to deliver oxygen in appropriate form and dosage in clinical practice.

Nanosponges as protective agent against photo degradation

The gamma-oryzanol (a ferulic acid ester mixture), an anti-oxidant and usually employed to stabilize food and pharmaceutical raw materials, moreover, used as a sunscreen in the cosmetics industry. Its applications are limited due to its high instability and photodegradation.

Removal of Organic Pollutants from Water

Betacyclodextrin Nanosponges are completely insoluble in water, have the property of encapsulating organic pollutants from water. Ceramic porous filters can be impregnated with these Nanosponges resulting in hybrid organic/inorganic filter modules. These hybrid filter modules were tested for the effective purification of water, employing a variety of water pollutants. It has been established that polycyclic aromatic hydrocarbons (PAHs) can be removed very efficiently (more than 95%). Representatives of the pollutant group of trihalogen methanes (THMs), monoaromatic hydrocarbons (BTX), and pesticides (simazine) can also be removed.

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