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Nanosponges: A Novel Trend for Targeted Drug Delivery

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ABSTRACT

Effective targeted drug delivery system has been a dream for a long time, but it has been largely frustrated by the complex chemistry that is involved in the development of new systems. Topical drug delivery system has many problems like poor permeability, skin irritation, allergic reactions etc. major problems of newly developed chemical entities is their poor solubility in water and pharmacokinetic issues. These poorly-water soluble drugs show many problems in formulating them in conventional dosage forms and the critical problems associated is its very low bioavailability. The invention of Nanosponge has become a significant step towards overcoming these problems. Nanosponge is tiny sponges with a size about a virus (250nm-1um), which can be filled with a wide variety of drugs. 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 method, applications of nanosponge, factor in the field of drug delivery.

Keywords: nanosponge, poor solubility, Biodegradable polymers, synthesis, preparation

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Introduction

Targeting the delivery of drugs has long been a problem for medical researches-how to get them to the right place in the body and how to control the release of the drug to prevent overdoses.effective targeted drug delivery systems has been a dream for long time now but it has been largely frustrated by the complex chemistry that is involved. (1,4)

The development of nanosponges is porous polymeric delivery systems that are small spherical particles with large porous surface. These are u sed for the passive targeting of cosmetic agents to skin there by achiving major benefits such as reduction of total dose, retention of cosmetion of dosage from on skin and avoidance of systemic absorption. This nanosponge can be effectively incorporated onto topical system for the prolonged release and skin retention thus reducing the variability in drug absorption, toxicity and improving patient compliance by prolonging dosing intervals.

Nanosponge is new class of material and made of microscopic particlas with new few nanometerswide cavities, in which a large variety of substances can be encapsulated. These particles are capable of carrying both lipophilic and hydrophilic substances and of improving the solubility of poorly water suitable molecules.nanosponge are tiny mesh-like structure that may revolutionize the treatement of many diseases and early trials suggest this tenchnology is up to five times more effective at delivering drugs for breast cancer than conventional method. These are solids in nature and it can be formulated as oral, parentral, topical or inhalational dosage forms.for oral administration, nanosponges may be disersed in matrix of excipients, dilutes, lubricants and anti-cacking agents which is suitable for the prepration of tablets or capsules. Nanosponges can significantly reduce the iriitation of drugs without reducing their efficacy. The nanosponges is about the size of a virus with a backbone(a scaffold structure)of naturally degreadable polyester. The long length polyester stands are mixed in solution with small molecules called cross- linkers that have an affinity for certain portions of the polyester.they cross link segments of the polyester to form a spherical shape that has many pockets shere drugs can be stored.the polyester is predictably biodegradable, which means that when it breaks up in the body, the drug can be released on a known schedule. (4).

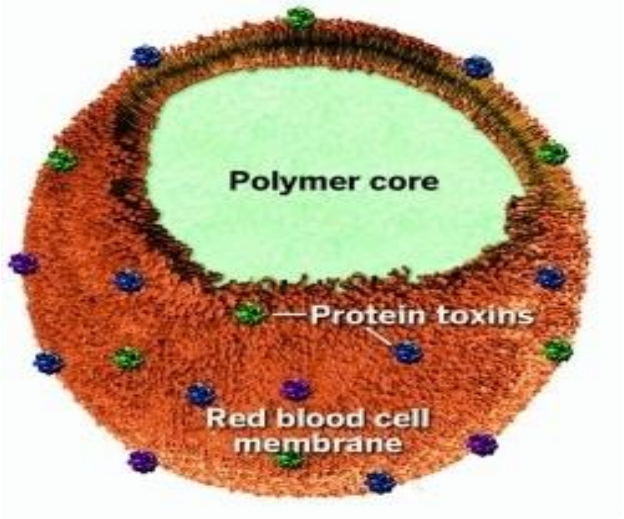

Fig.1:-Structure of Nanosponges

The nanosponges are encapsulating type of nanoparticles which encapsulates the drug molecules within its core.by the method of associating with drugs, the nanoparticles can be classified into encapsulating nanoparticles and conjugating nanoparticles. The first type is represented by nanosponges which are sponge-like nanoparticles containg many holes that carry the drug molecules. Nanocapsules. Nanocapsules such as poly(isobutyl- cyanoacrylate)(IBCA) are also encapsulating nanoparticles. They can entrap drugmolecules in their aquous core. The second category is complexing nanoparticles, which links to drugs thorough covakent bonds.(4).

Nanosponges are capable of providing solutions for several formulation related problems. Owing to their small ize and porous nature they can bind poorly-soluble drugs within the matrix and improve their bioavaibility.they can be bind poorly- soluble drugs within the matrix and improve their bioavability. They can be crafted for targeting drugs to specific sites,prevent drug and protein degredation and prolong drug release in a controlled manner.nanosponges are obtained by suitable cross linking process and also by different organic and inorganic materials.

Features of nanosponges

1. An important character of these sponges is their aqueous solubility; this allows the use of these systems effectively for drugs with poor solubility.
2. The nanosponges are capable of carrying both lipophilic and hydrophilic drugs.
3. They have been used for removal of organic impurities in water, as Nano –carriers for biomedical applications.
4. This technology offers entrapment of ingredients and reduced side effects, improved stability, increased elegance, and enhanced formulation flexibility.
5. Nanosponges are non irritating and non-mutagenic, non- allergic and nontoxic.
6. Extended release –continuous release up to 12th allows incorporation of immiscible liquid improves material processing –liquid can be converted to powders. they can be formed in a sub microns spherical particle. They can be obtained in a wide range of dimensions of the particle.
7. Nanosponges can disperse at molecules level, highly insoluble principles, stabilizing and protecting their structures, from chemicals, light, oxygen etc.
8. Efficacy and shelf life of drugs can be prolonged if compared to the non-complexes from by using nanosponges as drug delivery system, higher therapeutic activities are observed being the concentration of the active molecules the same.

Advantages

1. This technology offers entrapment of ingredients and reduces side effects
2. Improved stability, increased elegance and enhanced formulation flexibility.
3. These formulations are stable stable over range of PH 1to 11.
4. These formulations are stable at the temperature up to 1300C
5. These formulations are compatible with most vehicles and ingredients
6. These are self sterilizing as their average pore size is 0.25 where bacteria cannot penetrate.
7. They increase the bioavability of drug
8. They increase the solubility of poorly soluble drug.

Disadvantages

1. Nanosponges include only small molecules.[8]
2. Depend only upon loading

Chemicals used for the synthesis of nanosponge.

Table 1:-Chemicals used for the synthesis of nanosponge.

Polymers	Hyper cross linked Polystyrenes, Cyclodextrins and its derivatives like Methyl β-Cyclodextrin, Alkyloxycarbonyl-Cyclodextrins, 2-Hydroxy Propyl β-Cyclodextrins and Copolymers like Poly (valerolactone -allylvalerolactone), Poly (valerolactone-allylvalerolactoneoxepane-dione), Ethyl Cellulose and PVA
Cross-linkers	Diphenyl Carbonate, Diarylcarbonates, Di-Isocyanates, Pyromellitic anhydride, Carbonyl-di-Imidazoles, Epichloridrine, Glutarldehyde, Carboxylic acid dianhydrides, 2,2-bis(acrylamido) Acetic acid and Dichloromethan.
Apolar solvents	Ethanol, Dimethylacetamide, Dimethyl formamide

Methods for preparation of Nano sponges

a) Nanosponge prepared from hyper-cross linked β-cyclodextrin

100 mL of anhydrous dimethylformamide (DMF) were placed in a round bottom flask and 17.42 g of anhydrous β-cyclodextrin (15.34 mmol) were added to achieve complete dissolution. Then 9.96 g of carbonyl di imidazole (61.42 mmol) were added and the solution allowed reacting for 4 h at 100 ◦ C. Once the condensation polymerization was completed, the transparent block of hyper-cross-linked cyclodextrin was roughly ground and an excess of deionized water added to remove DMF. Finally, residual by-products or unreached reagents were completely removed by Soxhlet extraction with ethanol. The white powder thus obtained was dried overnight in an oven at60°C and subsequently ground in a mortar. The fine powder obtained was dispersed in water. The colloidal part that remained suspended in water was recovered and lyophilized. The nanosponges recovered are sub-micron in dimension and with a spherical shape. The cyclodextrin: cross-linker molar ratio can vary (i.e. 1:2, 1:4, and 1:8). Nanosponge can be classified according to the molar ratio with the cross-linker used in their preparation (i.e. Nanosponge, 1:4) [9]

b) Emulsion solvent diffusion method

In this method 2 phases are used in different proportion of organic and aqueous (ethyl cellulose and polyvinyl alcohol). The dispersed phase having ethyl cellulose and drug get dissolved in dichloromethane (20 ml) and a definite amount of polyvinyl alcohol added to 150 ml of aqueous continuous phase. Then, the mixture is stirred properly at 1000 rpm for 2hr. The required Nanosponge were collected by the process of filtration and kept for drying in oven at 40ºc for 24hr. Nanosponge which are dried were stored in desiccators and ensured of removal of residual solvents is done. [10]

c) Quasi-emulsion solvent diffusion

The Nanosponge prepared using the polymer in different amounts. The inner phase is prepared using Eudragit RS 100 and added to a suitable solvent. Drug used provided with a solution and dissolved under ultra-sonication at 35ºc. This inner phase added into external phase containing PVA act as emulsifying agent. The mixture is stirred at 1000-2000 rpm for 3hr at room temperature and dried in an air-heated oven at 40ºc for 12hr. [10]

Factors influencing Nanosponge formulation

Type of polymer

Type of polymer used can influence the formation as well as the performace of nanosponges. For complexation, the cavitity size of nanosponges should be suitable to accommodate a drug molecule of particular size.

Melting point of the substance is below 250°C

Type of drugs

Drug molecules to be complexed with nanosponges should have certain characteristics mentioned below(11)

Molecules weight between 100 and 400

Drug molecules consists of less than five condensed rings

Solubility in water is less than 10mg/mL

Temperature

Temperature changes can affect Drug/nanosponges complexation. In general, increasing in the temperature decreses the magnitude of the apperent stability constant of the drug/nanosponges complex may be due to a result of possible reduction of drug/ nanosponges interaction forces, such as van-der waal forces and hydrophobic forces with rise of temperature.

Method of prepration

The method of loading the drug into the nanosponges can affext drug/nanosponges complexation however, the effectiveness of a method depends on the nature of the drug and polymer, in many cases freeze drying was found to be most effective for drug complexation(12)

Degree of substitution

The complexation ability of the nanosponges May be greatly affected by type, number and position of the substituent on the parent molecule(12)

Characterization of Nanosponge

Characterization of Nanosponge

Inclusion complexes formed between the drug and nanosponge can be characterized by following methods.

Thermo-analytical methods

Thermo-analytical methods determine whether the drug substance undergoes some change before the thermal degredation 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 thermo gram obtained by DTA and DSC 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.

Microscopy studies

Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) can be used to study the microscopic aspects of the drug, Nanosponge 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.

X-ray diffractiometry and single crystal X-ray Structure analysis

Powder X-ray diffractiometry can be used to detect inclusion complexation in the solid . When the drug molecule is liquid since liquid have no diffraction pattern of their own, then the diffraction pattern of a newly formed substance clearly differs from that of uncomplexed Nanosponge. This difference of diffraction pattern indicates the complex formation. When the drug compound is a solid substance, a comparison has to be made between the diffractogram of the assumed complex and that of the mechanical mixture of the drug and polymer molecules .A diffraction pattern of a physical mixture is often the sum of those of each component, while the diffraction pattern of complexes are apparently different from each constituent and lead to a "new" solid phase with different diffractogram. Diffraction peaks for a mixture of compounds are useful in determining the chemical decomposition and complex formation. The complex formation of drug with Nanosponge alters the diffraction patterns and also changes the crystalline nature of the drug. The complex formation leads to the sharpening of the existing peaks, appearance of a few new peaks and shifting of certain peaks. Single crystal X-ray structure analysis may be used to determine the detailed inclusion

structure and mode of interaction. The interaction between the host and guest molecules can be identified and the precise geometrical relationship can be established Solubility studies The most widely used approach to study inclusion complexation is the phase solubility method described by Higuchi and Connors, which examines the effect of a Nanosponge, on the solubility of drug. Phase solubility diagrams indicate the degree of complexation

Infra-Red spectroscopy

Infra-Red spectroscopy is used to estimate the interaction between Nanosponge and the drug molecules in the solid state. Nanosponge bands often change only slightly upon complex formation and 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 Nanosponge. The technique is not generally suitable to detect the inclusion complexes and is less clarifying than other methods .The application of the Infra-red spectroscopy is limited to the drugs having some characteristic bands, such as carbonyl or sulfonyl groups. Infrared spectral studies give 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 diminishes to considerable extent and this helps in identifying the complex formation between the drug and Nanosponge.

Loading efficiency

The loading efficiency of Nanosponge can be by the quantitative estimation of drug loaded into Nanosponge by UV spectrophotometer & HPLC methods.

Particle size and polydispersity

The particle size can be determined by dynamic light scattering using 90 Plus particle sizer equipped with MAS OPTION particle sizing software. From this the mean diameter and polydispersity index can be determined. [13] [14] the polydispersity index (PDI) can also be measured from Dynamic light scattering Instruments. PDI is an index of width or spread or variation within the particle size distribution. Monodisperse samples have a lower PDI value, where as higher value of PDI indicates a wider particle size distribution and the polydisperse nature of the sample. PDI can be calculated by the following equation:

$$PDI = \Delta d/davg$$

Where,

Δd is the width of distribution denoted as SD and davg is the average particle size denoted as MV (nm) in particle size data sheet. [15]

Table 2:- Zeta potential

Poydispersity index	Type of dispersion
0-0.05	Momodisperse standard
0.05-0.08	Nearly monodisperse
0.08-0.7	Mid range polydispersity
0.7	Very polydisperse

Zeta potential is a measure of surface charge. It can be measured by using additional electrode in the particle size equipment [14]

In-vitro drug release study

Drug release from the Nanosponge can be measured across the dialysis membrane using Franz Diffusion cell with a diffusional area of 2.26 cm2 and receptor volume of 11ml. The dialysis membrane soaked in receptor medium for 8 hrs is used as a barrier between the donor and receptor compartment. A one gram nanosponge was placed on the membrane surface in the donor compartment that was sealed from the atmosphere with aluminum foil. The receptor compartment was filled with 11ml of phosphate buffer of pH 6.8 (skin pH).During the experiment, the solution of receptor side compartment was kept at 37±0.5oc and stirred at 100 rpm with Teflon-coated magnetic stirring bars. Aliquots were collected from the receptor compartment at designated time intervals and replaced by the same volume of fresh receptor solution to maintain sink condition and constant volume. The sample was analyzed using UV spectrophotometer [16]

Biopharmaceutical Classification System Class II Drugs

Table 3:-Biopharmaceutical classification system class ii drugs

Category	Drugs
Antianxiety drug	Lorazepam
Antiarrethmic agents	Amiodarone hydrochloride
antibiotics	Azithromycin, ciprofloxacin, erythromycin,ofloxacin, sulfamethoxazole
anticoagulants	Warfarin
anticonvulsant	Carbamazepine, clonazepam,felbamate, oxcarbazepine, primidone
Ant diabetic nad antihyperlipidemic drugs	Atrovastatin, finofibrate, glibenclamide, glipizide, lovastatin, troglitazone
Antiepileptic drugs	Phenytoin
Antifungal agents	Econazole nitrate,griseofulvin,itraconazole,ketoconazole,lansoprazole, vericonazole
Antihistamines	Erfenadine
Antihypertensive drugs	Felodepine, nicardipine, nifedipine, nisoldipine
Antineoplastic agents	Camptothecin, docetaxel, etoposide, exemestane, flutamide, irinotean, pacitaxel, raloxifene, flutamide, irinotecan, paclitaxel, raloxifene, tamoxifen, temozolamide, topotican
Antioxidants	Resveratrol

Antipsychotic drugs	Chlorpromazine hydrochloride
Antiretroviral	Indinavir, Nelfinavir, Ritonavir
Antiulcer drugs	Lansoprazole, Omeprazole
Anthelmintics	Albendazole, Mebendazole,Praziquantel
Cardiac drugs	Carvedilol, Digoxin, Talinolol
Diuretics	Chlorthalidone, Spironolactone
Gastroprokinetic agent	Cisapride
Immunosuppressant's	Cyclosporine, Sirolimus,Tacrolimus
NSAIDS	Dapsone, Diclofenac, Diflunisal,Etodolac, Etoricoxib,Flurbiprofen, Ibuprofen,Indomethacin, Ketoprofen,Nimesulide, Oxaprozin,Piroxicam Danazol, Dexamethazone
Steroids	Atovaquone, Melarsoprol,
Miscellaneous	Phenazopyridine, Ziprasidone

Applications of Nanosponge

1. Nanosponges for drug delivery Because of their nonporous structure, nanosponges can advantageously carry water insoluble drugs (Biopharmaceutical Classification System class-II drugs). These complexes can be used to increase the dissolution rate, solubility and stability of drugs, to mask unpleasant flavors and to convert liquid substances to solids [18]

2. Nanosponges as chemical sensors Nanosponges which are the type of " metal oxides" act as a chemical sensors which is used in highly sensitive detection of hydrogen using nanosponge titania. Nanosponge structure intially have no point of contact so there is less hinderance to electron transport and it results in higher 3D interconnect nanosponges titania which is sensitive to H2 gas[19]

3. Nanpsponge for oral delivery In oral application it forms the nanosponge system consist of pores which increase the rate of solubilization of poorly water soluble drugs which get entrapped the drug in pores. [20]

4. Solubility enhancement30: β-cyclodextrin based nanosponges of itraconazole have enhanced solubility of poorly soluble drug. The solubility increased by 50 folds compared to ternary dispersion system. Eg- copolyvidonum.

5. Nanosponges as a carrier for biocatalysts and release of enzymes, proteins, vaccines and Antibodies: It includes the process applied in industries which correlate with operational condition. Reactions which are not specific give rise to low yields and require high temperatures and pressures which consume large amount of energy and cooling water in down-stream process. This are the drawbacks can be removed by using enzymes as biocatalysts as this operate under high reaction speed, mild condition[21]

6. Antiviral application Nanosponges used in nasal, pulmonary route of administration. It provide specificity to deliver antiviral drug on RNA to lungs or nasal route through nanocarriers for targeting virus which may cause infection to RTI such as influenza virus, rhinovirus. Drugs used as nanocarrriers are- Zidovudine, Saquinavir [22].

7. Cancer Targeting drug to specific site avoiding the obstacle created by immune system. Different cancer cells had been treated by Nanosponge like breast cancer or fast acting glioma type with help of single dose of injections [23]

8. Oxygen Delivery System Characterized by using α, β and Ɣ cyclodextrins and this are suspended in water and get saturated with water. A silicone form of membrane can also be used for oxygen permeation with the help of nanosponge/ hydrogel system [23]

Other Applications

Biomedical Applications

Cyclodextrin based carbonate nanosponges were used to form inclusion complexes with three different gases i.e. methylcyclopropene, oxygen and carbon dioxide. The complexation of oxygen or carbon dioxide could be useful for many biomedical applications. In particular the oxygen filled nanosponges could supply oxygen to the hypoxic tissues which are present in various diseases [24, 25]. Nanosponges can selectively soak up biomarkers for the diagnosis. One study concluded that nanosponges can harvest rare cancer marker from blood [26].

Analytical Applications

The microporous hypercross-linked nanosponges have been used in selective preparation of inorganic electrolytes by size exclusion chromatography. The three dimensional nanosponges will play important role in the fractionalization of peptides for proteomic applications [27].

For Hydrogen Storage

Hydrogen is considered as an alternative energy for the future, but one of the problems to be solved before it achieves the versatility of other fuel sources as oil is how to store it. Recent studies claim to find materials that could act as sponges that absorb hydrogen and store it until ready to use. But until now had not found a material with the capability to store hydrogen under the necessary pressure and temperature. A team of scientists from the Universities of Newcastle and Liverpool have discovered a new class of materials which composed of long carbon chains linked by metal atoms. To crystallize, these molecules form cavities that are less than a nanometer, which are connected by "windows" that are even smaller than a molecule of hydrogen. While these cavities are filled, hydrogen fits through the windows, because the carbon chains are flexible. But once filled the cavities, the chains lose their flexibility, thus closing the windows. Consequently, it can be loading the high-pressure hydrogen gas, and when pressure levels drop, forming a sort of molecular size seal. Although so far the materials created by this team of scientists do not have enough capacity for most applications that use fuel cells, their work represents a new approach to the problem, and nanosponges could potentially have a key role in the hydrogen storage system in future [28,29,30].

In Agriculture

Plants that grow more have a better appearance, what counts is not just the climate, but technology. This is so for functionalized nanosponges (FNS), an agricultural invention that allows plants to grow more and improve their appearance by feeding them with an optimal dosage of micro-nutrients and active ingredients that are necessary for healthy growth. Another notable advantage is that nanosponges allow a significant reduction in the use of herbicides and fertilizers, thereby increasing productivity and improving both the environmental and cultivation

quality levels. Nutritive substances (such as iron and zinc), or active ingredients, are encapsulated in the nano-cavities during the synthesis process. The nutritive substances incorporated in the nanosponges are dosed and fed to the plants in a very precise manner, "drop by drop", thereby optimising photosynthesis. The significant reduction in the use of fertilizers makes their cultivation similar to that of organic products, although production levels are much higher. This means lower production costs and access to healthier food for many more people. For example, FNSs with iron solve one of the most common problems with plants, ironchlorosis (yellowing of leaves), thereby allowing a more efficient photosynthesis conversions and higher plant growth rate. One of the major advantages of this innovative product is the possibility of making ad-hoc formulations for diverse applications [31,32].

In Floriculture

Nanosponges have been recently developed and proposed for delivering nutrients, preservative and anti-ethylene compounds in order to improve cut off flower life [33,34].

In Food Industry

Nanosponges are useful for masking, reduction and elimination of bitter components from fruit juices and other dietary products by selective combination of polymer and cross-linker [32].

For Water Purification

Cyclodextrin nanosponges can be used for the removal of organic pollutants from water. B-cyclodextrin 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 (>95%). Representatives of the pollutant group of trihalogen methanes (THMs), monoaromatic hydrocarbons (BTX), and pesticides (simazine) can also be removed (>80%) [62]. Cyclodextrin Nanosponge can strongly bind

For Oil Cleaning

Nanotechnology allows for the creation of new materials with unique and enhanced properties, and has specific implications for the electronics and biomedical industries. One of the latest nanotech discoveries came through researchers at Rice University and Penn State. They found that adding boron to carbon during nano tube construction creates spongy blocks that have amazing oil absorbing properties. The nanosponges are extremely hydrophobic, giving it the natural tendency to float on water and not absorb it even when submerged. It is also ferromagnetic, meaning it can be controlled or retrieved using a magnet. The density of the material is extremely low, making the available volume for oil uptake very high. Not only can it soak up over 100 times its weight in oil as it floats on the water, but it can store the oil for later retrieval. The oil can then be squeezed out or burned off, allowing the sponge to be reused. The researchers also tested the sponge robustness and reusability in the lab, where it maintained elasticity even after 10,000 compressions. Safe to say, this material has tremendous power as an agent for surface oil cleanup [35, 37].

As Chemical Sensors

Metal oxide nanosponges as chemical sensors used in highly sensitive detection of hydrogen using nanosponge Titania. In a nanosponge structure, however there are no contact points, consequently there is much less hindrance to electron transport and results in higher sensor stability. 3-dimensionally (3D) interconnected nanosponge titania (NST) is highly sensitive to H2 gas. 3D interconnected metal oxide nanostructure is a promising class of sensor material through which the ultra-high chemical sensitivity of nanostructures can be harnessed in practical devices.

As Novel Flame Retardants

A novel flame retardant in tumescent system, aimed to improve the fire stability of ethylene vinyl acetate copolymer (EVA), has been prepared by melt blending of the copolymer and a complex of cyclodextrin nanospongephosphorus compounds. As compared to traditional systems, this complex is stable in processing conditions, has the advantage that nanosponges act as both carbon sources and foam forming agents while the phosphorus compounds are able to directly generate phosphoric acid in-situ. In this context, cyclodextrin nanosponges undergo dehydration in presence of the acid source, generating water vapour and char, and thus protecting the copolymer against combustion [35, 38].

Against Pore Forming Toxins and Superbug Infections Detoxification treatments such as toxin-targeted anti-virulence therapy offer ways to cleanse the body of virulence factors that are caused by bacterial infections, venomous injuries and biological weaponry. Because detoxification platforms existing such as antisera, monoclonal antibodies, small-molecule inhibitors and molecularly imprinted polymers act by targeting the molecular structures of toxins; customized treatments are required for different diseases. Researchers at the University of California, San Diego prepared biomimetic toxin nanosponges that functions as a toxin decoy in-vivo. The nanosponges are consists of a polymeric nanoparticle core surrounded by red blood cell (RBC) membranes, absorbs membrane damaging toxins and diverts them away from their cellular targets, combating drug-resistant infections (Figure 3), such as those caused by methicillin-resistant Staphylococcus aureus (MRSA). One red blood cell membrane can be used as a cloak for more than 3,000 of these stealthy nanosponges. Once the nanosponges are fully loaded with toxins, they are safely disposed of by the liver. As reported in a mouse model, the nanosponges markedly reduced the toxicity of staphylococcal alpha-haemolysin (a toxin) and thus improved the survival rate of toxin-challenged mice. This biologically inspired toxin nanosponge presents a detoxification treatment that can potentially treat a variety of injuries and diseases caused by poreforming toxins [37].

Micropatterning of Mammalian Cell Developing artificial scaffolding structures in-vitro in order to mimic physiological-relevant situations in-vivo is critical in many biological and medical arenas including bone and cartilage generation, biomaterials, small-scale biomedical devices, tissue engineering, as well as the development of nanofabrication methods. Group of researchers, using simple physical principles (photolithography) and chemical techniques (liquid vapour deposition) build non-cytotoxic scaffolds with a nanometer resolution using silicon substrates as the backbone. This method merges an optics-based approach with chemical restructuring to modify the surface properties. Through this nanofabrication-based approach, they developed hydrophobic oxidized silicon nanosponges and then probed cellular responses-examining cytoskeletal and morphological changes in living cells through a combination of fluorescence

Microscopy and scanning electron microscopy-via culturing Chinese hamster ovary cells, HIG-82 fibroblasts and Madin-Darby canine kidney cells on these silicon Nanosponge. This study has demonstrated the potential applications of using these silicon-based nanosponges for influencing cellular behaviours at desired locations with a micro or nanometer level [37].

Conclusion

The Nanosponge has the ability to include either lipophilic or hydrophilic drugs and release them in a controlled and predictable manner at the target site. By controlling the ratio of polymer to the cross-linker the particle size and release rate can be modulated. Nanosponges enable the insoluble drugs and protect the active moieties from physicochemical degradation and controlled release. Because of their small size and spherical shape nanosponges can be developed as different dosage forms like parenteral, aerosol, topical, tablets and capsules. They are tiny mesh-like structures that may revolutionize the treatment of many diseases and this technology is five times more effective at delivering drugs for cancer than conventional methods. Topical nanosponges can be more patient compliant and provide sufficient patient benefits by reducing repeated doses and side effects. Nanosponge can be effectively incorporated into topical drug delivery system for retention of dosage form on skin. Hence present study concludes that nanosponges may play an important role for the treatment of different diseases. Nanosponges are nano sized colloidal carrier so they easily penetrate through skin. Due to their small size and porous nature. They can bind poorly- soluble drugs within the matrix and improve their bioavailability of drug and they also increase the solubility of poorly soluble drugs.

They are based on Nano, polymer-based spheres that can suspend or entrap a wide variety of substances and then be incorporated into a formulated product such as a gel, lotions, cream, ointments, liquid or powder. This technology offers entrapment of ingredients and thus reduced side effects improved stability, increases elegance and enhanced formulation flexibility. Nanosponges can be effectively incorporated into topical drug delivery system for retention of dosage form on skin and also use for oral delivery of drugs using bioerodible polymers, especially for colon specific delivery and controlled release drug delivery system thus improving patient compliance by providing site specific drug delivery system and prolonging dosage intervals.

Nanosponge is nano sized colloidal carrier so they easily penetrate through skin. Due to their small size and porous nature. They can bind poorly- soluble drugs within the matrix and improve their bioavailability of drug and they also increase the solubility of poorly soluble drugs.

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