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OVERVIEW OF NANOSPONGES

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Abstract : The recent advance in nanotechnology has lead to the development of targeted drug delivery system. The ideal delivery systems solubilize the drug, lead the therapy to the target site to fulfill the individual need of patient and disease stage. Effective targeted drug delivery to specific sites is the significant problem which is being faced by the researchers. The discovery of nanosponges has become a significant step in overcoming certain problems such as drug toxicity, poor bioavailability and release of drug in a predictable fashion as they can accommodate both hydrophilic and hydrophobic drug. Nanosponges exhibit a porous structure in nature which has the unique ability to entrap the drug moieties and offers a merit of desire release. Nanosponges are tiny sponges that can circulate in the body to reach the specific site and binds on the surface to release the drug in a controlled and predictable manner. Nanosponges technology has been explored widely for the delivery of drugs for oral administration, topical administration and parenteral administration.

Keywords : Nanosponges, Targeted drug delivery, Characteristics, Method of preparation, Application

INTRODUCTION

Despite having high therapeutic efficacy, many molecules of currently available medications are still regarded as being poorly soluble in water, which causes partial absorption and limited bioavailability. The key factor limiting the potential of such medications in these situations is their solubility. Poorly soluble pharmaceuticals contribute to formulation failures during the development phase.[1] "Nanosponge" refers to nanoparticles with porous structures. Nanosponges are extremely small sponges, with an average diameter of less than 1 μm and the size of a virus. Nanosponges are three-dimensional, solid, porous, biocompatible drug delivery systems that may entrap both hydrophilic and hydrophobic medications and solve the issues of drug toxicity and poor bioavailability. The development of nanosponges has shown to be a crucial step in overcoming the complexity.

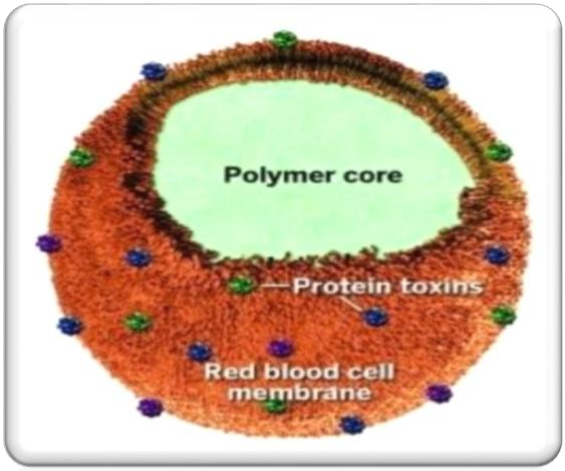


fig.1 : structure of nanosponges

Nanosponges can attach poorly-soluble medications inside the matrix and improve their bioavailability at specific target sites. They can also cling to the surface and start releasing the drug in a regulated and predictable way because of their small size and porous nature.[2] Nanosponges have demonstrated their ability to keep up with the developments in nanomedicine, responding well to the demand for targeted therapies intended to increase the efficacy and minimise the side effects of the medications.[3] Different organic and inorganic ingredients, as well as an appropriate cross-linking procedure, are used to create nanosponges. Upon generating complexes like inclusion and non-inclusion complexes, these can enclose various molecules. These can prolong the release of the medicine for up to 12 hours and are non-mutagenic, non-irritating, and non-toxic in nature. By transforming microsponges and microspheres into nanosponges, the drawbacks of these materials can be avoided.[4] Tiny sponges are included in a particular dosage form, which circulates throughout the body until it reaches the target region. Sponges cling to the target surface and start to release the medicine in a controlled and predictable manner. The drug will be more effective for a given dosage since it can be released at the precise target spot rather than spreading throughout the body.[5] Nanosponges are soluble in water but do not chemically break down there. After being diluted with water, they are utilised as a transport fluid. They can be used to mask unpleasant tastes in both liquid and solid forms. The chemical linkers enable the nanosponges to attach to the target location preferentially. One can create dosage forms for oral, parenteral, topical or inhalation using the nanosponges. They are by definition solid. The Complexes can be dissolved in a mixture of excipients, diluents, lubricants, and anti-caking agents that are suitable for making oral capsules or tablets. They might successfully integrated into topical hydrogel for topical delivery. These can easily be combined with sterile water, saline, or other aqueous solutions for parenteral delivery.[6] Early studies indicate that the use of nanosponges, which are tiny mesh-like structures that may change the treatment of numerous diseases, can transport medications for breast cancer up to five times more effectively than current approaches.[5]

Characteristics of Nanosponges[7,8,9,10]

- Nanosponges offer a variety of diameters (1 μm or less) with adjustable cavity polarity.
- Simple thermal desorption, solvent extraction, microwaves and ultrasounds can all be used to replicate them.
- Nanosponges may transport both hydrophilic and lipophilic medications.
- They guard the medication against physicochemical deterioration.
- Nanosponges are compositions that can withstand temperatures of up to 130°C and a pH range of 1 to 11.
- Nanosponges are biodegradable, non-toxic, non-allergic and non-irritating.
- Depending on the dose therapy, the drug profiles can range from quick, medium, or slow release.
- By creating inclusion and non-inclusion complexes, nanosponges can encapsulate a variety of compounds.
- Nanosponges can attach most effectively to the target site than to chemical linkers.
- A variety of compounds can be transported, captured and released selectively than to their three-dimensional structure.
- Since only tiny amounts of the medicine come into contact with healthy tissue while using nanosponge, there are less negative effects.
- Nanosponge create a controlled release of drugs, which is one of their key advantages.
- By altering the crosslinker to polymer ratio, nanosponges with size of viruses can be created.
- Nanosponge enhanced formulation flexibility, elegance, and stability.

Advantages of nanosponges[11,12,13]

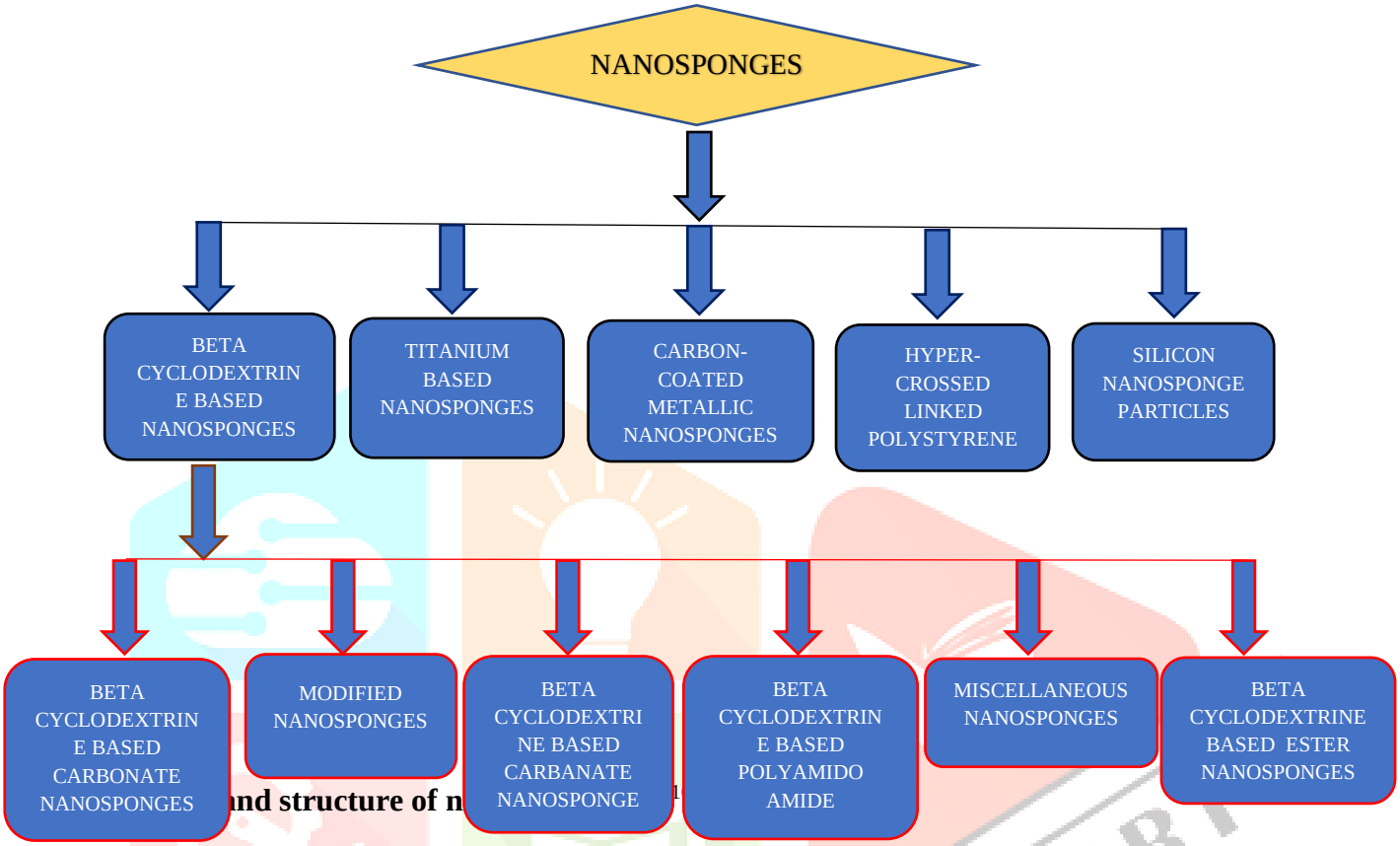
- Drug delivery to a specific target spot.
- They make drugs that aren't very soluble into solution.
- Less negative side effects because less of the medicine comes into contact with healthy tissue.
- They increase the bioavailability of drug.
- These compositions work well with the majority of substances and vehicles.
- These formulations can be economical and free-flowing.
- This technique minimises adverse effects and offers ability to entrap a wide range of substances.
- Enhanced formulation flexibility, increased elegance and improved stability.
- These are self-sterilizing because bacteria cannot pass through their 0.25 μm typical pore size.
- A nanosponge offers extended release with continuous activity for up to 12 hours.
- It lessens irritability and increases tolerance, which improves patient compliance.
- Immiscible liquids can be included, improving material processing, and liquids can be turned into powders.
- Has the ability to turn liquid substances into solid substances and to hide disagreeable flavours.
- Predictable and controlled drug release.
- The preparation and development method requires simple chemistry.

- By altering the cross-linker to polymer ratio, particles can be made smaller or larger.

Disadvantages of nanosponges[11,13]

- It relies on the drug molecules' loading capabilities.
- It only contains tiny molecules; no huge molecules are present.

Types of nanosponges[10]



nd structure of n[1]

Nanosponges are intricate structures that are often made of long, linear molecules that are folded into a roughly spherical shape, around the size of a protein, through cross-linking. Cyclodextrin has been cross-linked with organic carbonates to create common nanosponges. Three components make up the majority of nanosponges, that are, Polymer, Cross-linking agent and drug substance

Polymer: The kind of polymer utilised can have an impact on how successfully nanosponges develop and function. The cavity size of a nanosponge should be adequate to fit a drug molecule of a specific size for complexation. The substitutable functional and active groups determine whether a polymer can be cross-linked. The medicine to be encapsulated and the required release determine the polymer to be used. The polymers can be employed to interact with the drug substance or to surround the drug. The polymer should possess the ability to bind with the particular ligands in order to facilitate targeted medication release, e.g. Hyper cross linked polystyrene, Cyclodextrin and its derivatives like Methyl beta cyclodextrin, Alkyloxycarbonyl Cyclodextrin, 2-Hydroxyl propyl β-Cyclodextrin, Ethyl cellulose, Polymethylmethacrylate and Copolymers, e.g. Poly (valerolactone -allylvalerolactone oxepanedione) ,Poly vinyl alcohol

Crosslinking agent: The choice of crosslinking agent is influenced by the polymer's structure and the medicine be synthesised, e.g. Dichloromethane, Carbonyl diimidazole , Carboxylic acid dianhydride, Diarylcarbonates, Diisocynate Epichloridine 2,2-bis (acrylamido) Acetic acid Diphenyl

Drug substance: The drug substance should bear following features, to be suitable for nanosponges.

• A molecular mass of 100–400 daltons.

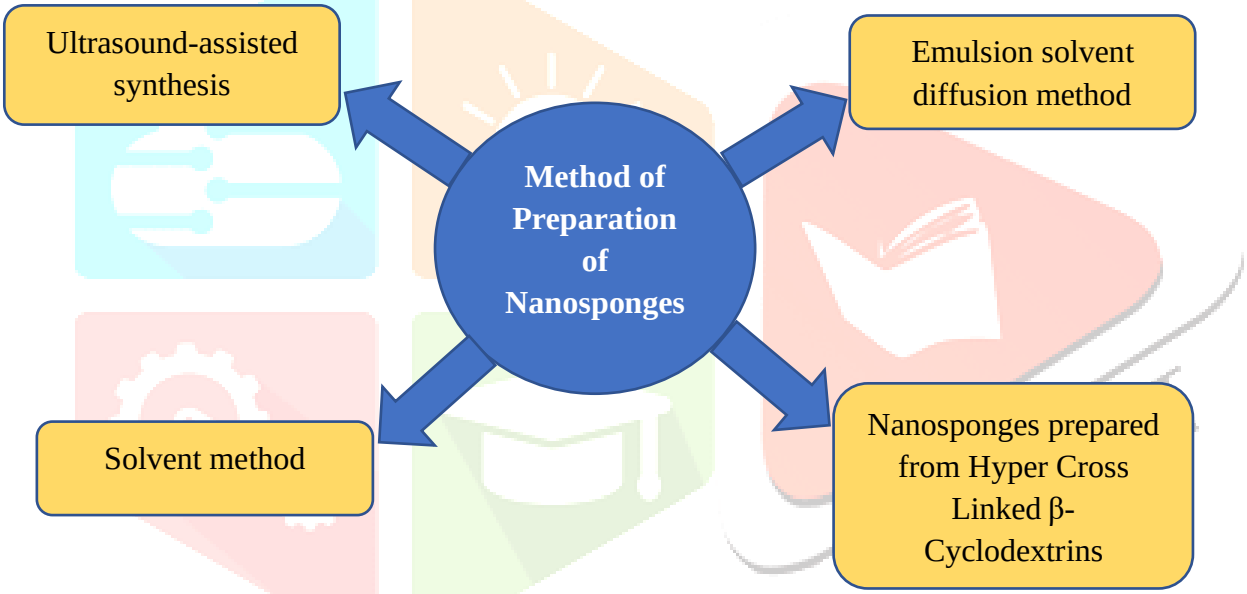
• The drug's molecule has no more than four condensed rings.

• Water solubility less than 10 mg/ml.

• The substance's melting point below 250 °C.

Methods of preparation of Nanosponges[5]

Various delivery systems require different types of nanosponges. By maximising formulation factors like the drug:polymer ratio, the polymer:crosslinking agent ratio and the agitation or stirring speed, different nanosponges can be made.



Ultrasound-assisted synthesis[17,18]

By combining polymers with cross-linkers without the need of a solvent and using sonication, nanosponges can be created. In this procedure, the polymer and cross-linker are combined in a flask at the proper molar ratio. The flask is then placed in an ultrasonic bath 90°C temperature and filled with water. The aforementioned combination is sonicated for a few hours. After cooling the aforementioned mixture, the final product should be roughly shattered. To eliminate non-reacted polymer, the resultant is rinsed in water. It is then refined using ethanol-based soxhlet extraction and subsequent drying produces nanosponges.

Emulsion solvent diffusion method[19,20]

Organic and aqueous phases are employed in this approach. Polyvinyl alcohol is present in the aqueous phase and drugs and polymers are present in the organic phase. After the drug and polymer have been dissolved in a suitable organic solvent, this phase is slowly added to the aqueous phase and agitated for two or more hours. The nanosponges are then collected by filtering, washed and dried in the air at ambient temperature for 24 hours or in a vacuum oven at 40°C.

Solvent method[19,21]

The polymer should be combined with a suitable solvent, preferably a polar aprotic solvent like dimethyl formamide or dimethyl sulfoxide. The extra cross-linker is then added to this mixture, preferably in a 4 to 16 molar to 1 molar ratio. Perform the reaction for 1 to 48 hours at a temperature range from 10 °C to the solvent's reflux temperature. The carbonyl compounds di methyl carbonate and carbonyl di imidazole are the most used crosslinkers. Allow the solution to cool at room temperature when the reaction is finished. Add the result to a large amount of bi-distilled water, recover it by filtering under vacuum and then purify it using extended soxhlet extraction using ethanol. Dry the product in a vacuum and then grind it in a mill to obtain homegeneous powder.

Nanosponges prepared from Hyper Cross Linked β-Cyclodextrins[22,23]

A cross-linker such as diaryl carbonates, dimethyl carbonate, diphenyl carbonate, carbonyl di-imidazoles, carboxylic acid dianhydrides and 2, 2-Bis (acrylamido) acetic acid is used to react cyclodextrin to create these materials. To connect various molecules, sponges surface charge density, porosity and pore diameters can be altered. Low cross linking nanosponge provides a rapid medication release.

B-cyclodextrin nanosponges were made by adding 17.42g of anhydrous -CD to 100ml of dimethyl formamide (DMF) in a round-bottomed flask in order to completely dissolve it. 9.96g (61.42 mmol) of carbonyl di-imidazole was then added and the solution was allowed to react at 100 °C for 4 hours. The translucent block of highly cross-linked cyclodextrin was roughly crushed after condensation polymerization was finished in order to eliminate DMF. Finally, soxhlet extraction with ethanol was used to thoroughly eliminate any remaining byproducts or unreacted chemicals. The resulting white powder was then mortar-dried for the entire night at 60°C in an oven. The obtained fine powder was dissolved in water. The colloidal component that was still floating in the water was retrieved and lyophilized. The produced nanosponges have a spherical form and sub-micron dimensions.

Loading of drug into nanosponges[17,19]

Pre-treatment of nanosponges is necessary to achieve an average particle size of less than 500 nm. To avoid the presence of aggregates, nanosponges are suspended in water and sonicated. The solution is then centrifuged to extract the colloidal fraction. The sample is dried by freeze drying after the supernatant has been separated. Nanosponges are manufactured as an aqueous solution. The extra medication is dispersed in Nanosponges aqueous suspension and the suspension is kept under constant stirring for the precise period of time needed for complexation. After complexation, centrifuge the complex drug to separate it from the uncomplexed drug. Then, using freeze drying or solvent evaporation, the solid nanosponges crystals were produced. Nanosponges crystal

structure is crucial in the complex formation with medication. According to a study, paracrystalline nanosponges and crystalline nanosponges have distinct loading capabilities.

Mechanism of drug release from nanosponges[24]

The active ingredient is given to the vehicle in an encapsulated form since nanosponges have an open structure and lack a continuous membrane around them. From the particles into the vehicle, the encapsulated active ingredient can travel freely until the vehicle becomes saturated and equilibrium is reached. The vehicle carrying the active ingredient becomes unsaturated as soon as the product is applied to the skin, disrupting the balance. Thus, until the vehicle is either absorbed or dried, active compounds from nanosponge particles start to flow into it. The release of active substance to skin continues for a considerable amount of time even after the retention of the nanosponge particles on the stratum corneum of the skin.

Factors influencing nanosponges formation[7,14]

Type of polymer: The performance of nanosponges as well as their production can be influenced by the type of polymer utilised. The cavity size of nanosponges should be appropriate to hold a medication molecule of a specific size for complexation.

Type of drug: The features of the drug molecules that will be complexed with nanosponges should match those listed above.

Temperature: Changes in temperature can impact how well drugs and nanosponges interact. In general, when temperature rises, the strength of the drug/nanosponges complex's apparent stability constant decreases, which may be a result of the potential reduction of drug/nanosponges contact forces like van-der Waal forces and hydrophobic forces.

Method of Preparation: The way a drug is loaded onto a nanosponge can impact how the drug and nanosponge interact. Freeze drying was discovered to be the most effective approach for drug complexation in many circumstances. The efficiency of a method depends on the nature of the drug and polymer.

Degree of Substitution: The kind, number and position of the substituents on the parent molecule may have a significant impact on the nanosponges capacity for complexation. The capability of crosslinking increases as the number of substituents increases. As crosslinking increases, highly porous nanosponges are formed as a result of additional linkages between the polymers, creating a mesh-like network.

Factors affecting drug release from nanosponges[23]

- The entrapped actives chemical and physical characteristics.
- Physical characteristics of the sponge system, such as pore volume, pore diameter and resilience.
- The characteristics of the final vehicle in which the sponges are dispersed.
- Imperative criteria include compositions, pore properties and particle size.
- External triggers, such as pressure, temperature, and active solubility.
- Pressure: Rubbing or pressure can cause the medicine in nanosponges to spill out onto the skin.

- Temperature: Some entrapped actives may be too viscous to spontaneously flow from sponges onto skin at ambient temperature, but higher skin or environment temperatures may cause the flow rate to increase and ultimately lead to drug release.
- Solubility: Water-soluble substances, such as antiperspirants and antiseptics, are released from sponges when water is present.

Applications of nanosponges

Cancer Therapy[25] Nanosponges can be used to encapsulate the anticancer medications. The nanosponge drug delivery technique is three to five times more efficient compare to conventional injectables. In that, cells either cling to the nanosponges or suck them up. They carefully off-load their lethal material. Less adverse effects and more effective treatment at the same dose are two advantages of targeted medicine delivery. Paclitaxel, camptothecin, and other medications are being employed as anticancer agents at the moment.

Sustained delivery system[26] By utilising the right polymers and crosslinking agents, the drug release kinetics from nanosponges can be achieved with a protracted release profile over time. Additionally, after being encapsulated, volatile compounds like essential oils can be stored on nanosponges to delay their release.

Protection from light or degradation[26] Nanosponges can also be utilised as carriers to shield encapsulated compounds from degradation caused by light, chemicals, and enzymes. Consequently, the molecule's stability and potency are increased.

Solubility enhancement[27] The pores in the nanosponge system speed up the solubilization of poorly soluble medicines by encasing them there. Surface area has greatly expanded and the rate of solubilization has accelerated due to nanoscale. Drugs in BCS class 2 have a low solubility and a slow absorption rate. They do, however, show improved solubilization efficiency and the required drug release properties when they are made with nanosponge. Table 2 is a list of several BCS Class II drugs that can be formed into nanosponges.

table 2:biopharmaceutical classification system class ii drugs

Category of drug	List of drug
Antianxiety drugs	Lorazepam
Antiarrhythmic agents	Amiodarone hydrochloride
Antibiotics	Azithromycin, Ciprofloxacin, Erythromycin
Anticoagulant	Warfarin
Anticonvulsants	Carbamazepine, Clonazepam, Oxycarbazepine,
Antidiabetic and Antihyperlipidemic drugs	Atorvastatin, Fenofibrate, Glibenclamide, Glipizide
Antiepileptic drugs	Phenytoin
Antihistamines	Terfenadine
Antifungal agents	Econazole nitrate, Griseofulvin, Itraconazole
Antihypertensive drugs	Felodipine, Nicardipine, Nifedipine, Nisoldipine
Antineoplastic agents	Camptothecin, Docetaxel, Etoposide, Exemestane, Flutamide, Irinotecan,Paclitaxel, Raloxifene, Tamoxifen, Temozolamide, Topotecan
Antipsychotic drugs	Chlorpromazine Hydrochloride
Antiretrovirals	Indinavir, Nelfinavir, Ritonavir, Saquinavir
Antiulcer drugs	Lansoprazole, Omeprazole
Antioxidants	Resveratrol
Anthelmintics	Albendazole, Mebendazole, Praziquantel
Cardiac drugs	Carvedilol, Digoxin, Talinolol
Diuretics	Chlorthalidone, Spironolactone
Immunosupressants	Cyclosporine, Sirolimus, Tacrolimus
NSAIDs	Dapsone, Diclofenac,Diflunisal,Etodolac
Gastroprokinetic agent	Cisapride
Steroids	Danazol, Dexamethazone

Antiviral application[28] In the ocular, nasal, and pulmonary delivery routes, nanosponges can be helpful. Targeting viruses that cause RTIs, such as respiratory syncytial virus, influenza virus, and rhinovirus, can be done by using nanocarriers to carry antiviral medications or small interfering RNA (siRNA) to the nasal epithelia and lungs. Additionally, they can be utilised for HBV, HSV, and HIV. The medications zidovudine, saquinavir, interferon and acyclovir (Eudragit based) are now used as nanosponges delivery systems.

Blood Purification[25] With the use of nanosponges, blood purification is achievable. Haemodialysis has been used to treat kidney failure, which is characterised by the buildup of many intermediate molecular weight toxins (MMW 10–20). Dialysis Low molecular weight solutes can pass through membranes, however the elimination of strong MMW toxins is still not complete. In order to selectively permit the MMW toxins to penetrate into the porous matrix while size-excluding serum albumins, Malik et al. investigated a more focused method. They employed a method of membrane emulsification.

Gas drug delivery system[25] Through the nanosponges drug delivery system, the patient can receive a variety of gases, including oxygen, carbon dioxide, 1-methylcyclopropane, and others. In a variety of illness states, nanosponges have the capacity to store and deliver oxygen to hypoxic tissue. By generating inclusion complexation with cyclodextrin-based carbonate nanosponges, oxygen is supplied to the hypoxic tissue. The

most widely used cyclodextrin among the three forms, such as cyclodextrin, which was pre-saturated with oxygen before administration.

Nanosponges in Drug Delivery[29] Due to the nanoporous nature of nanosponge, they are ideal carriers of molecules and/or medications that are insoluble in water (BCS Class-II pharmaceuticals). The solubility, stability, and rate of dissolution of BCS class II medicines can all be improved by nanosponge. Some medications with low solubility are successfully administered using nanosponges. They can be created as oral, parenteral, topical, or inhalation dosage forms due to their solid structure.

Nanosponge in protein drug delivery[29] Protein encapsulation, enzyme immobilisation and subsequent regulated administration and stabilisation are all possible with the help of nanosponge. Bovine serum albumin (BSA) protein is preserved in lyophilized form since it is unstable in solution form. Poly (amidoamino) nanosponges based on swellable cyclodextrin increase the stability of proteins like BSA.

Topical drug delivery system[10] Antibiotics, topical anaesthetics and antifungals are just a few of the types of medication that can be easily synthesised into topical nanosponges. In this context, many techniques, such as the emulsion solvent diffusion approach, can be used to create nanosponges.

Modulating drug release[31] The main disadvantage of the standard, commercially accessible medication is that it requires regular administration. As a result, a medicine that has been put into the nanosponge is kept and released gradually over time. According to research by Vyas et al., hydrophilic cyclodextrin nanosponges are a powerful drug carrier in formulations for quick release and can alter the pace at which a drug releases and boost drug absorption across biological barriers. The finest carriers for an anticancer medicine like doxorubicin are hydrophobic cyclodextrin nanosponges because they hold peptide and protein pharmaceuticals, provide prolonged release, and preserve the drug while it travels through the stomach. This medication releases relatively slowly at pH 1.1, but releases more quickly at pH 7.4.

Other Applications

- Application of Analysis[31] By using size exclusion chromatography, inorganic electrolytes have been selectively prepared using the microporous hypercross-linked nanosponges. The fractionalization of peptides for proteomic applications will heavily rely on the three-dimensional nanosponges.
- Considering Chemical Sensors[32] Titania nanosponges made of metal oxides are employed as chemical sensors for the highly sensitive detection of hydrogen. However, because there are no contact sites in a nanosponge shape, there is significantly less resistance to electron transport, which increases sensor stability. Nanosponge Titanium (NST) that is coupled in three dimensions (3D) is very sensitive to H2 gas. A promising kind of sensor material that takes use of the ultra-high chemical sensitivity of nanostructures is 3D interconnected metal oxide nanostructure.
- Purification of Water[32] Water organic contaminants can be removed using cyclodextrin nanosponges. B-cyclodextrin nanosponges have the ability to encapsulate organic contaminants from water despite being entirely insoluble in water. These nanosponges can be used to saturate ceramic porous filters, creating hybrid organic/inorganic filter modules. Utilising a range of water contaminants, these hybrid

filter modules were tested for their effectiveness in the purification of water. Polycyclic aromatic hydrocarbons (PAHs) have been shown to be extremely effectively (>95%) eliminated. Trihalogen methanes (THMs), monoaromatic hydrocarbons (BTX), and insecticides (simazine) are also capable of being eliminated (>80%). Strong binding is possible using cyclodextrin nanosponge.

- For Hydrogen storage[33,34,35] The storage of hydrogen is one of the issues that needs to be resolved before it can rival the adaptability of other fuel sources like oil as an alternative energy source for the future. According to recent studies, there are materials that could store hydrogen until it is needed by acting as sponges to absorb it. However, up to this point, no material had been discovered that could store hydrogen at the required pressure and temperature. A group of researchers from Newcastle and Liverpool Universities have uncovered a new category of materials that are made of lengthy carbon chains connected by metal atoms. These molecules create "windows" even smaller than a hydrogen molecule in order to connect their nanometer-sized holes, which are necessary for the crystal to form. Hydrogen can pass through the windows when these cavities are filled, thanks to the flexibility of the carbon chains. But after the cavities are filled, the chains become rigid and close the windows. As a result, it might be filling with high-pressure hydrogen gas and then, when the pressure drops, forming a kind of molecular seal. Although the materials developed by this team of researchers do not now have sufficient capacity for the majority of fuel cell applications, their work marks a novel approach to the issue, and nanosponges may one day play a significant role in the hydrogen storage system.
- In Agriculture[36,37] More-growing plants have greater aesthetics; technology is equally as important as climate. This is true for functionalized nanosponges (FNS), a technological advancement in agriculture that feeds plants with the ideal amount of micronutrients and active chemicals required for healthy growth, enabling them to grow larger and have a better appearance. Another noteworthy benefit of nanosponges is their ability to significantly reduce the use of fertilisers and pesticides, which boosts production and raises the environmental and agricultural quality standards. During the manufacturing process, nutritive components (such as iron and zinc) or active chemicals are encapsulated in the nano-cavities. Incorporating nutrients into nanosponges allows for very precise dosing and feeding of the plants, or "drop by drop" feeding, which maximises photosynthesis. Although production levels are substantially greater, their cultivation is comparable to that of organic items due to the significant reduction in the usage of fertilisers. As a result, many more people will have access to healthier food at lower production costs. For instance, iron-containing FNSs eliminate one of the most prevalent issues with plants, iron chlorosis (leaf yellowing), enabling more effective photosynthetic conversions and faster plant growth. Making custom formulas for a variety of applications is one of this revolutionary product's key benefits.
- In Floriculture[38,34] Recently, it has been suggested to use nanosponges to supply nutrients, preservatives and anti-ethylene chemicals to lengthen the life of cut flowers.
- In Food Industry[37] By carefully combining a polymer with a cross-linker, nanosponges are beneficial for disguising, reducing and eliminating bitter components from fruit juices and other nutritional goods.

- For Oil Cleaning[39,40] Nanotechnology has particular importance for the electronics and biomedical industries since it enables the development of novel materials with distinctive and improved features. Researchers at Penn State and Rice Universities made one of the most recent findings in nanotechnology. They discovered that when carbon and boron are combined to form nanotubes, spongy blocks are produced that have exceptional oil-absorbing capabilities. Due to the extraordinary hydrophobicity of the nanosponges, they naturally have a tendency to float on water and not absorb moisture even when submerged. It is also ferromagnetic, which enables magnetic retrieval or control. Due to the material's extremely low density, a large amount of space is open for oil absorption. It may store the oil for later retrieval in addition to absorbing nearly 100 times its weight in oil as it floats on the water. The sponge can then be reused when the oil has been squeezed out or burnt off. The sponge's durability and usability were also evaluated in the lab, where it maintained its elasticity even after 10,000 compressions. It's safe to say that this material is a highly effective surface oil cleanup agent.
- As Novel flame Retardants[39] By melting the copolymer with a complex of cyclodextrin nanospongephosphorus compounds, a novel flame retardant in tumescent system that aims to increase the fire stability of ethylene vinyl acetate copolymer (EVA) has been created. In contrast to conventional systems, this complex is stable under processing circumstances, has the benefit that nanosponges serve as carbon sources and foam-forming agents and has the capability for the phosphorus compounds to produce phosphoric acid in-situ directly from phosphorus compounds. In this situation, cyclodextrin nanosponges dehydrate when the acid source is present, producing water vapour and char and shielding the copolymer from combustion.
- Against pore forming Toxins and superbug infections[40] Toxin-targeted antivirulence therapy, for example, offers a technique to rid the body of virulence factors brought on by bacterial infections, poisonous wounds and biological weapons. Customised treatments are necessary for various diseases because detoxification platforms like antisera, monoclonal antibodies, small-molecule inhibitors, and molecularly imprinted polymers function by targeting the molecular structures of toxins. Biomimetic poison nanosponges were created by University of California, San Diego researchers and they serve as a toxic decoy in living organisms. The nanosponges, which have red blood cell (RBC) membranes surrounding a polymeric nanoparticle core, absorb toxins that damage membranes and divert them away from their cellular targets in order to treat drug-resistant infections, including those brought on by methicillin-resistant Staphylococcus aureus (MRSA). More than 3,000 of these stealthy nanosponges can hide behind a single red blood cell membrane. The liver securely disposes of the nanosponges once they have been fully loaded with poisons. According to research done on mice, the nanosponges significantly decreased the toxicity of the toxin staphylococcal alphahaemolysin and consequently increased the survival rate of the mice exposed to the toxin. This biologically inspired toxin nanosponge offers a detoxifying method that may be used to treat a range of ailments and injuries brought on by poreforming toxins.
- Micropatterning of Mammalian cell[40] Mammalian Cell Micropatterning In many biological and medical fields, such as bone and cartilage generation, biomaterials, small-scale biomedical devices, tissue

engineering, as well as the development of nanofabrication methods, artificial scaffolding structures that mimic physiologically relevant situations *in vivo* are essential. Using silicon substrates as the foundation, a team of researchers creates non-cytotoxic scaffolds with a nanoscale resolution using photolithography, a straightforward physical process. In order to change the surface properties, this technique combines a chemical reformation strategy with an optics-based approach. They created hydrophobic oxidised silicon nanosponges using this nanofabrication-based methodology and they then studied cellular responses by cultivating Chinese hamster ovary cells, HIG-82 fibroblasts and Madin Darby canine kidney cells on these silicon nanosponges. They looked at cytoskeletal and morphological changes in living cells using a combination of fluorescence microscopy and scanning electron microscopy. This study has shown how these silicon-based nanosponges could be used to modify cellular behaviour at specific areas at the micro- or nanometer scale.

Comparison of some effective vesicular systems(EVS)[5]

These colloidal drug delivery methods include nanosponge, ethosome, transferosome, liposome and niosome. They are all nanometer-sized. However, nanosponge improved the stability of the medicine. Liposome, niosome and transferosomes all have some stability issues that are discussed below in the table.

table 3: comparison of nanosponge with vesicular system

Liposome	Liposome consists of one or more concentric lipid bilayers, which enclose an internal aqueous volume.	The composition of liposomes is phospholipids and cholesterol.	Stability problems: due the formation of ice crystals in liposomes, the subsequent instability of bilayers leads to the leakage of entrapped material. The oxidation of cholesterol and phospholipids also leads to the formulation instability.
Niosome	Niosomes are non-ionic surfactant vesicles obtained on hydration of synthetic nonionic surfactants, with or without incorporation of cholesterol or other lipids.	They composed of non-ionic surfactants and cholesterol.	Stability problems: fusion, aggregation, Sedimentation and leakage on storage. The Hydrolysis of encapsulated drug.
Ethosome	Ethosomes are lipid vesicles containing phospholipids, alcohol (ethanol and isopropyl alcohol) in relatively high concentration and water.	They composed mainly of phospholipids, high concentration of ethanol and water.	Ethosomes has initiated a new area in vesicular research for transdermal drug delivery which can provide better skin permeation and stability than liposomes. Application of ethosomes provides the advantages such as improved entrapment and physical stability.
Transferosome	Transferosomes are vesicular system consisting of phosphatidyl choline and surfactant.	They consist of phospholipid and surfactants.	Stability problem: chemically unstable because of their pre disposition to oxidative degradation.

Nanosponge	Nanosponge are novel class of hypercrosslinked polymer based colloidal structures consisting of solid nanoparticls with colloidal sizes and nanosized cavities.	They composed of polymers and cross linkers.	Nanosponge are chemically and physically stable. They increase the stability and bioavailabiliy modify drug release and reduce side effects.

table 4: some examples of nanosponges drug delivery with their formulations[5]

Drug	Nanosponges vehicle	Therapeutic activity	Attributes	Administration route
Voriconazole	Ethyl cellulose, Poly (methyl methacrylate), Pluronic F-68	Antifungal	Controlled release	Oral, topical
Atorvastatin	Ethyl cellulose, β-Cyclodextrin	Anti hyperlipidemic	Enhanced bioavailability	Oral
Econazole nitrate	Ethyl cellulose Polyvinyl alcohol	Antifungal	Enhanced drug solubility	Oral, topical
Isoniazid	Ethyl cellulose Polyvinyl alcohol	Antitubercular	Enhanced drug solubility	Oral
Tamoxifen	β-CD, carbonyl diimidazole	Antiestrogen	Enhanced bioavailability, solubility	Oral
Camptothecin	β-cyclodextrin	Antineoplastic	Haemolytic activity, Cytotoxicty	Parenteral

table 5: marketed preparation of nanosponges[41]

Drug	Administration route	Trade name	Dosage form
Dexamethasone	Dermal	Glymesason	Tablet
Iodine	Topical	Mena- gargle	Solution
Alprostadil	Intravenous	Prostavastin	Injection
Piroxicam	Oral	Brexin	Capsule

CONCLUSION

Drugs that are both hydrophilic and lipophilic can be encapsulated or accumulated using nanosponges as a drug delivery device by generating a complex. They are capable of precisely and safely delivering the medication to the intended location. Topical preparations like lotions, creams, ointments and other liquid or powder forms can contain nanosponges. The benefit of this technology is that it may focus the drug to a particular spot, reducing side effects while improving stability, formulation flexibility and patient compliance. Other areas where nanosponges can be used in include agrochemistry, cosmetics, biomedicine, bioremediation, and catalysis.

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