AMERICAN JOURNAL OF PHARMTECH RESEARCH
Journal home page: http://www.ajptr.com/

A Review On- Hydrogel

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ABSTRACT

Hydrogel product constitute a group of polymeric material, the hydrophilic structure of which render them capable of holding large amount of water in their three dimensional networks. Due to their high water content, porosity and soft consistency, they closely simulate natural living tissue, more so than any other class of synthetic biomaterials. Furthermore, hydrogels can be formulated in a variety of physical forms, including slabs, microparticles, nanoparticles, coatings, and films. As a result, hydrogels are commonly used in clinical practice and medicine for a wide range of applications, including Tissue engineering and Regenerative medicine, Diagnostics, Cellular immobilization, separation of biomolecules or cells, and barrier materials to regulate biological adhesions. This biomaterial can hold large amount of biological fluids and swell. When swell, they are soft and rubbery and resemble the living tissue exhibiting excellent biocompatibility. The prime objective of this article is to concern the classification of hydrogel on different bases, properties of hydrogel and its method of preparation and physical and chemical characteristics of these products.

Keywords: Hydrogel Properties, Method of Preparation, Applications, Current research on hydrogels.

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Received 03 May 2018, Accepted 22 May 2018

Please cite this article as: Malpure PS *et al.*, A Review On- Hydrogel. American Journal of PharmTech Research 2018.

INTRODUCTION

Hydrogels are polymeric networks that take in and keep huge quantities of water. There are hydrophilic groups in the polymeric network which become hydrated in aqueous media thus forming hydrogel structure.[1] Another definition is that it is a polymeric material that exhibits its ability to swell and retain a significant fraction of water within its structure, but will not dissolve in water. They possess a degree of flexibility very similar to natural tissue due to their large water content. The ability of hydrogel to absorb water arises from hydrophilic functional group attached to polymeric backbone, while their resistant to dissolution arises from crosslinks between network chains.[2]

Researcher over the years, have defined in hydrogel many different ways. The most common of these hydrogel is a water swollen, and cross-linked polymeric network produced by the simple reaction of one or more monomers.

During last two decades, natural hydrogels were replaced by synthetic hydrogels which has long service life, high capacity of water absorption and high gel strength. Synthetic polymers usually well-defined structure that can modify to yield tail or able degradability and functionality. Hydrogels are called 'reversible' or 'physical' gels if molecular entanglements and/or secondary force such as ionic, H-bonding or hydrophobic forces play the main role in forming the network.

Hydrogels are polymers that can retain many times their own weight in water. They are polymers of carboxylic acids. The acid groups ionise in water, leaving the polymer with several negative charges along its length. This has two effects. Firstly, the negative charges repel each other and the polymer is forced to expand. Secondly, polar water molecules are attracted to the negative charges. This increases the viscosity of the resulting mixture because the polymer chain now takes up more space and resists the flow of solvent molecules around it. The polymer is in equilibrium with the water around it, but the equilibrium can be disturbed in a number of ways. If the ionic concentration of the solution is increased, for example by adding salt, the positive ions attach themselves to the negative sites on the polymer, effectively neutralizing the charges. This causes the polymer to collapse in on itself again. Adding alkali removes the acid ions and causes the position of equilibrium to move to the right; adding acid has the opposite effect. There are a large number of hydrogels and they expand and contract at different pH values, temperatures and ionic concentrations. By using a mixture of monomers to create the polymer these characteristics can be fine-tuned.[3]

Advantages[4]

1. Hydrogel is more elastic and stronger.
2. Hydrogel possess good transparent properties and easy to modification.
3. Due to their significant water content they possess a degree of flexibility very similar to natural tissue.
4. They are biocompatible, biodegradable and can be injected.
5. Hydrogel have ability to sense change pH, temperature, or the concentration of metabolite and release their load as result of such a change.
6. Release of Medicines or nutrients timely.

Disadvantages [5]

1.High cost.

2.Non-adherent and may need to be secured by secondary dressing and also cause sensation felt by movement of the maggot.

3.Difficult to sterilize.

4.In contact lens less deposition hypoxia, dehydration and red eye reactions.

HYDROGEL TECHNICAL FEATURES

The functional features of an ideal hydrogel material can be listed as follows: [6]

1. The highest absorption capacity in saline.
2. Desired rate of absorption depending on the application requirements
3. The lowest soluble content and residual monomer.
4. The highest durability and stability in the swelling environment and during the storage.
5. Colorlessness, colorlessness, and absolute non-toxic.

Properties of Hydrogel

1. Swelling Properties: A small change in environmental condition may trigger fast and reversible changes in hydrogel. The alteration in environmental parameters like electric signal, pH, temperature, and presence of enzyme or other ionic species may lead to a change in physical texture of the hydrogel.[7]

2. Mechanical properties: The mechanical properties can vary and be tuned depending on the purpose of the material. It is possible to obtain a gel with higher stiffness increasing the crosslinking degree or lowering it by heating the material. The changes in mechanical properties link to a wide range of variables and causes and different analysis must be made according to the material.[8]

3. Polymers used in hydrogels: Hydrogels are prepared from natural and synthetic polymers.

4. Natural polymers: - Chitosan, gelatin, alginates, fibrin.

5. Synthetic polymers: - Vinyl acetate, acryolic acid, methacrylate-vinyl 2 pyrrolidine.
6. Biocompatible properties: Biocompatibility is the ability of a material to perform with an appropriate host response in a specific application. Biocompatibility consists basically of two elements: (a) bio-functionality i.e. the ability of material to perform the specific task for which it is intended. (b) bio-safety i.e. appropriate host response not only systemic but also local (the surrounding tissue), the absence of mutagenesis, cytotoxicity. [9]

CLASSIFICATION OF HYDROGEL PRODUCTS

Hydrogel can be classified on different bases as detailed below:

I. Classification based on source [10]

1. Natural hydrogels: Natural hydrogels are biodegradable, biocompatible and good cell adhesion properties. There are two major types of natural polymers which are used to produce natural hydrogels are proteins such as collagen, gelatin and, lysozyme, polysaccharides such as hyaluronic acid, alginate and Chitosan.
2. Synthetic hydrogels: They are more useful as compare to natural hydrogels because they can be engineered to have a much wider range of mechanical and chemical properties than their natural counter parts. Polyethylene glycol based hydrogels are one class of the widely used material in biomedical application due to their non-toxicity there compatibility and low immunogenicity.
3. Hybrid hydrogels: They are the combination of natural and synthetic polymer hydrogels. To combine the advantages of both synthetic and natural hydrogels many naturally occurring biopolymers such as dextran, collagen, Chitosan, have been combined with synthetic polymers such as poly (*N*-isopropylacrylamide) and polyvinyl alcohol.

II. Classification according to polymeric composition [11]

1. Homo-polymeric hydrogels: Homo-polymeric hydrogels are referred to polymer network derived from a single species of a monomer, which is a basic structural unit comprising of any polymer network. Homopolymers may have cross-linked skeletal structure depending on the nature of the monomer and polymerization technique.
2. Co-polymeric hydrogels: Co-polymeric hydrogels are comprised of two or more different monomer species with at least one hydrophilic component, arranged in a random, block or alternating configuration along the chain of the polymer network.
3. Multi-polymer interpenetrating polymeric hydrogel (IPN): An important class of hydrogels, having network system which is made of two independent cross-linked synthetic or natural

polymer components. In semi-IPN hydrogel, one component is a cross-linked polymer and other component is a non-cross-linked polymer.

III. According to the biodegradability

1. Biodegradable hydrogels: Hydrogels are biodegradable many polymers created by nature are biodegradable, such as Chitosan, fibrin and agar. Poly (aldehyde guluronate), Polyanhydrides and poly (*N*-isopropyl acrylamide) are examples of synthetic biodegradable polymers.
2. Non-biodegradable hydrogels: Various vinylated monomers or macromers such as 2-hydroxyl ethyl methacrylate, methoxyl poly (ethylene glycol), 2- hydroxyl propyl methacrylate and acryl amide are widely applied in the preparation of non-biodegradable hydrogels.

IV. Classification based on configuration[12]

The classification of hydrogels depends on their physical structure and chemical composition can be classified as follows:

1. Amorphous (non-crystalline).
2. Semi crystalline: A complex mixture of amorphous and crystalline phases.
3. Crystalline.

V. Classification based on type of cross-linking [13]

Hydrogels can be divided into two categories based on the chemical or physical nature of the cross-link junctions.

1. Chemically cross-linked networks have permanent junctions.
2. Physical networks have transient junctions that arise from either polymer chain entanglements or physical interactions as hydrogen bonds, or hydrophobic interactions.

VI. Classification based on physical appearance

Hydrogels appearance as matrix, film, or microsphere depends on the technique of polymerization involved in the preparation process.

VII. Classification according to network electrical charge [12]

Hydrogels may be categorized into four groups on the basis of presence or absence of electrical charge located on the cross linked chains:

1. Nonionic (neutral).
2. Ionic (including anionic or cationic).
3. Amphoteric electrolyte (ampholytic) containing both acidic and basic groups.
4. Zwitter ionic (polybetaines) containing both anionic and cationic groups.

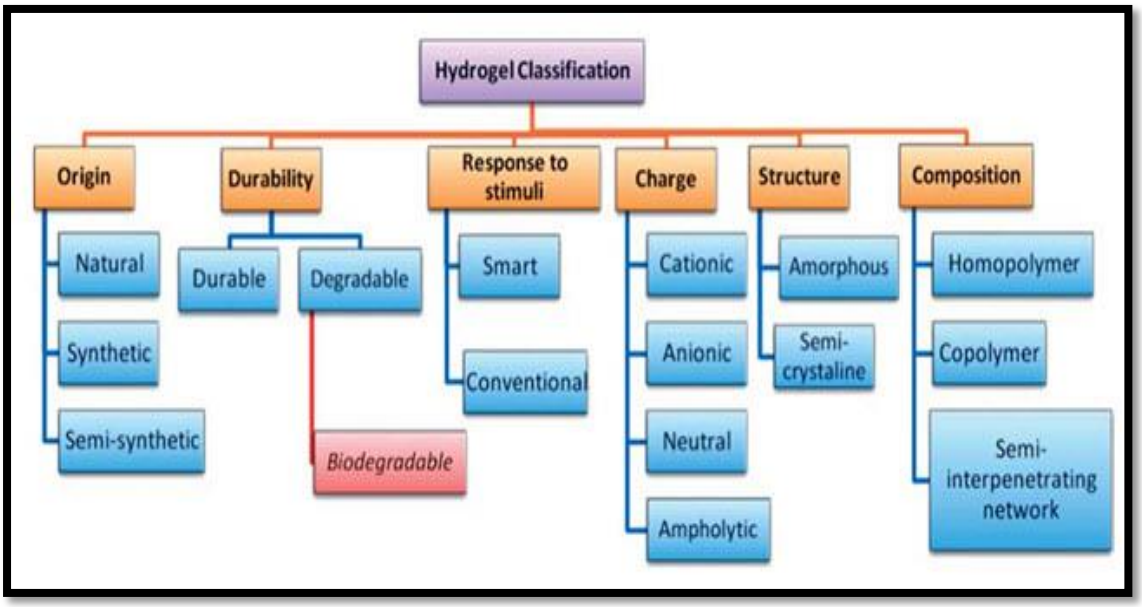

Figure 1: Flow chart of Hydrogel Classification.[14]

HYDROGEL PREPARATION METHODS

Hydrogels are polymer networks having hydrophilic properties. While hydrogels are generally prepared based on hydrophilic monomers, hydrophobic monomers are sometimes used in hydrogel preparation.

In general, hydrogels can be prepared from either synthetic polymers or natural polymers. The synthetic polymers are hydrophobic in nature and chemically stronger compared to natural polymers. Their mechanical strength results in slow degradation rate, but on the other hand, mechanical strength provides the durability as well. These two opposite properties should be balanced through optimal design. Also, it can be applied to preparation of hydrogels based on natural polymers provided that these polymers have suitable functional groups or have been functionalized with radically polymerizable groups. The polymerization techniques have been described below:

Bulk polymerization

Bulk hydrogels can be formed with one or more types of monomers mainly include vinyl monomers for the productions of hydrogels. Usually, a small amount of cross-linking agent is added in any hydrogel formulation. Radiation, ultraviolet, or chemical catalysts is used for the initiation of the polymerization reaction. The initiator is chosen which depends upon the type of monomers and solvents being used. The polymerized hydrogel may be produced in a wide variety of forms including rods, particles, films and membranes, and emulsions. [15]

Free radical polymerization

The main monomers which are used in this method for the preparation of hydrogels are such as acrylates, vinyl lactams and amides. These polymers have suitable functional groups or have been functionalized with radically polymerizable groups. This method involves the chemistry of typical free-radical polymerizations, which includes propagation, chain transfer, initiation, and termination steps. For the radical generation in the initiation step a wide variety of thermal, ultraviolet, visible, and redox initiators can be utilized, the radicals react with the monomers which convert them into active forms.[16]

Solution polymerization

In these ionic or neutral monomers are mixed with the multifunctional crosslinking agent. The polymerization is initiated thermally by UV-irradiation or by a redox initiator system. The major advantage of the solution polymerization over the bulk polymerization is the presence of solvent serving as a heat sink. The prepared hydrogels is washed with distilled water to remove the initiator, the soluble monomers, oligomers, cross-linking agent, and extractable polymer, and other impurities. Solvents used water–ethanol mixtures, water, ethanol, and benzyl alcohol. [17]

Suspension polymerization

This method is employed to prepare spherical hydrogel micropartical with size range of 1μm to 1mm. in this method the monomer solution is dispersed in non-solvent forming fine droplet, which is stabilized by stabilizer. The polymerization initiated by thermal decomposition of free radical. The prepared microparticle washed to remove un-reacted monomers cross-linking reagent and initiator. [18]

Grafting to a support

Grafting involves the polymerization of a monomer on the backbone of a preformed polymer. The polymer chains are activated by the action of chemical reagents, or high energy radiation treatment. The growth of functional monomers on activated macroradicals leads to branching and further to crosslinking. [19]

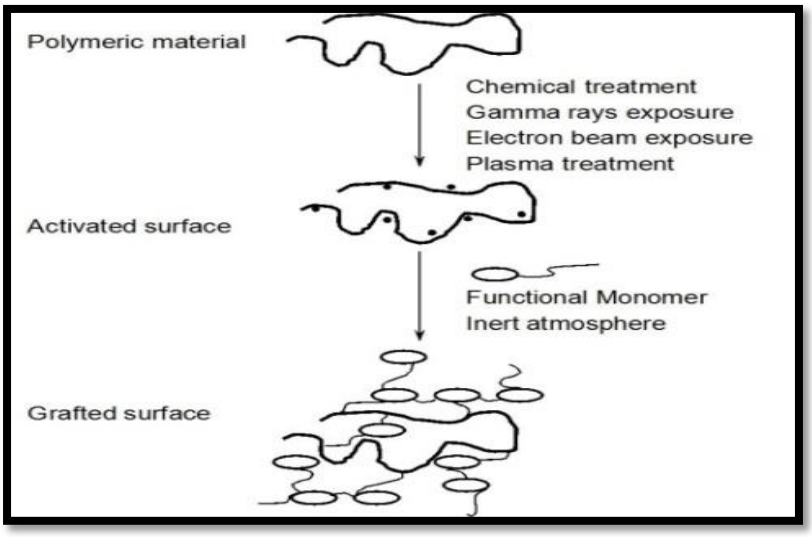

Figure 2: Grafting of a monomer on preformed polymeric backbone leading to infinite branching and cross-linking.

Polymerization by irradiation

For the preparation of hydrogels of unsaturated compounds the initiators such as the ionizing high energy radiation, like gamma rays and electron beams, has been used. The irradiation of aqueous polymer solution results in the formation of radicals on the polymer chains. Recombination of the macro-radicals on different chains results in the formation of covalent bonds, so finally, a cross-linked structure is formed. [20]

Physical cross-linking

It is the most common and easy routes for hydrogel formation by cross linking of polymers through physical interactions. This physical cross linking includes interaction of ions such as hydrogen bonding, polyelectrolyte complexation and hydrophobic association.

Complex coacervation

Formation of complex coacervate gels by mixing of polyanions with a polycations. The underlying principle of this method is that polymers with opposite charges stick together and form soluble and insoluble complexes depending on the concentration and pH of the respective solutions. One such example is coacervating polyanionic xanthan with polycationic chitosan. Proteins below its isoelectric point are positively charged and likely to associate with anionic hydrocolloids and form polyion complex hydrogel. [19\

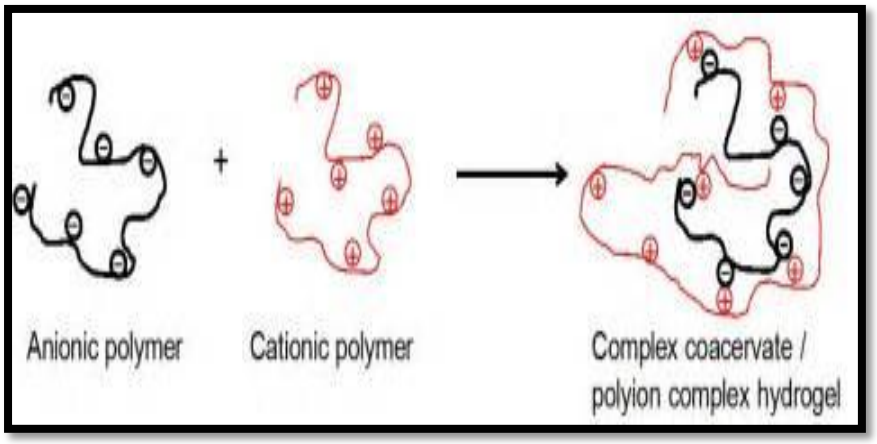

Figure 3: Complex coacervation between a polyanion and a polycation.

DRUG RELEASE MECHANISM [21]

Diffusion controlled:

Most common drug release mechanism for hydrogel is Diffusion controlled. Fick's law of diffusion with either constant or variable diffusion coefficients is commonly used in modeling diffusion controlled release. Drug diffusivities are generally determined empirically or estimated a prior using free volume, hydrodynamic, or obstruction-based theories.

Chemically controlled:

Chemically-controlled release is used to describe molecule release determined by reactions occurring within a delivery matrix. The most common reactions that occur within hydrogel delivery systems are cleavage of polymer chains via hydrolytic or enzymatic degradation or reversible or irreversible reactions occurring between the polymer network and releasable drug. Under certain conditions the surface or bulk erosion of hydrogels will control the rate of drug release. Alternatively, if drug-binding moieties are incorporated in the hydrogels, the binding equilibrium may determine the drug release rate.

Swelling controlled:

Swelling-controlled release occurs when diffusion of drug is faster than hydrogel swelling. The modeling of this mechanism usually involves moving boundary conditions where molecules are released at the interface of rubbery and glassy phases of swollen most common drug release mechanism of hydrogel is diffusion controlled.

CHARACTERIZATION OF HYDROGEL

The important features for characterization of hydrogels are as follows:

pH

pH of hydrogels is measured by using digital pH meter.[22]

Scanning Electron Microscopy (SEM)

SEM can be used to provide information about the sample's composition, surface topography, and other properties such as electrical conductivity.

Fourier Transform Infrared Spectroscopy

FTIR studies were carried out for hydrogel with and without drug. Hydrogen bonding has a significant influence on the peak shape and intensities, generally causing peak broadening and shifts in absorption to lower frequencies. On analyzing the graphs of hydrogel with and without drug, we determine the backbone structure of hydrogel with drug. [23]

Swelling measurement

Method A

According to this method the dry hydrogel is immersed in deionized water for 48 hours at room temperature on a roller mixer. After swelling, the hydrogel is filtered by a stainless steel net of 30 meshes (681 μm). The swelling is calculated as follows.

$$\text{Swelling} = W_s - W_d / W_d$$

Where, W_s is the weight of hydrogel in swollen state and W_d is the weight of hydrogel in dry state.

Method B

Alternatively, to measure the swelling of hydrogel, in a volumetric vial the dry hydrogel (0.05-0.1g) is dispersed into sufficiently high quantity of water (25-30 ml) for 48 hrs at room temperature. The mixture is then centrifuged to obtain the layers of water bound material and free unabsorbed water. The free water is removed and the swelling can be measured according to Method A.

Method C

According to this method, the dry gel is immersed in deionized water for 16 h at room temperature. After swelling, the hydrogel is filtered using a stainless-steel net of 100-mesh. Swelling is calculated as follows.

$$\text{Swelling} = C/B*100$$

Where, C is the weight of hydrogel obtained after drying and B is the weight of the insoluble portion after extraction with water.[24]

X-ray diffraction

Diffraction analysis is the estimation of crystalline or amorphous characteristics. It is used to understand whether the polymers retain their crystalline structure or they get deformed during the processing pressurization process. The diffraction analysis is quite a popular study for the morphological characterization of hydrogels.

Rheology

The viscosity of the gel formulations is determined using Brookfield viscometer with spindle no. 7 at 100 rpm at the temperature of 250 ^{c}. [25]

Spreadibilty study

The apparatus is made of wooden block with scale and two glass slides having a pan mounted on a pulley. Excess formulation is placed between two glass slides and 100 gm weight is placed on upper glass slide for 5 minutes to compare the formulation to achieve uniform thickness. Weight can be added and the time to separate the two slides is taken as spreadibilty time.

$$S= (M \times L) / T$$

Where S is spreadibilty, M is weight tied on upper slide, L is length of glass slide and T is time taken in seconds. [26]

Skin irritancy test

Skin irritancy tests are conducted on rabbits. The preparation is applied on two rabbits and the area is protected with gauze or bandage. After 24 hours the formulation is removed and the area is checked for any signs of edema and erythema. Average irritation scores= (erythema scores + edema reaction scores) / time interval. [27]

APPLICATIONS

1. **Wound healing:** Hydrogels have the ability to hold water and drug in them due to their cross linked structure. Due to their water holding ability they can hold and retain wound exudates. Polyvinyl pyrrolidine or polyacrylamide in the form of a gel containing 70-95% water.[28]
2. **Colon Specific Hydrogels:** Colon specific hydrogels of polysaccharide have been specifically designed because of presence of high concentration of polysaccharide enzymes in the colon region of GI. Dextran hydrogel is formulated for colon- specific drug delivery.
3. **Drug delivery in GI tract:** Hydrogels delivers drugs to specific site in the GIT. In presence of micro flora drug loaded with colon specific hydrogels show tissue specificity and change in the pH or enzymatic action which causes degradation of drug. [29]
4. **Rectal Delivery:** Hydrogels showing bio adhesive properties are used for rectal drug delivery. [30]
5. **Transdermal Delivery:** Various hydrogel based drug delivery device are formed to deliver drug through transdermal route. Hydrogel based formulations are being explored for transdermal iontophoresis to obtain enhanced permeation of products viz. hormones and nicotine.

6. **Drug delivery in the oral cavity:** Drug is incorporated into hydrogels and delivers to oral cavity for local treatment of diseases of the mouth, such as stomatitis, fungal diseases, periodontal disease, viral infections, and oral cavity cancers.[31]
7. **Gene delivery**: Change in composition of hydrogels leads to effective targeting and delivery of nuclei acids to specific cells for gene therapy. Hydrogels has more potential application in the treatment of many genetic o acquired diseases.[28]
8. **Tissue Engineering:** Micronized hydrogels are used to deliver macromolecules into cytoplasm of antigen presenting cells. Natural hydrogels material is used for tissue engineering include agarose, methylcellulose and other naturally derived products.[32]
9. **Ocular drug delivery:** Hydrogels are most widely used in ocular drug delivery system. Hydrogel show Controlled or sustain release in order to reduce the frequency of dosing or to increase the effectiveness of the drug by localization at its site of action, decreasing the dose required or providing uniform drug delivery.[33]

Figure 4: Applications of hydrogels.

OTHER APPLICATIONS OF HYDROGELS[34]

Watering beads for plants

Simple application of hydrogels consists in rough powders of polyacrylamide or potassium polyacrylate matrix sold with a huge range of names (Plant-Gel, Super Crystals, and Water-Gel

Crystals) and used as long term reservoir of water for plant growth in gardening, domestic and sometimes industrial horticulture. As Chalker-Scott from Washington State University pointed out in her publications on the topic, since the commonly used watering crystals are made out of non-renewable materials, whose monomers can be toxic (e.g. acrylamide), the potential risks of their usage are way higher than the benefits of water storage and controlled release that can, in addition, be obtained in many other ways with lower environmental impact.

Diapers

An interesting application of hydrogel's thermodynamically affinity for water, as not fancy as it can be, is the production of super-adsorbent diapers with the property of being dry even after a considerable adsorption of fluids. The development of hydrogel-containing diapers, most of them loaded with different formulations of sodium polyacrylate, in the past two decades cut down on a huge number of dermatological conditions related to a prolonged contact with wet tissues.

Perfume delivery

During the nineties patents describing volatile species delivery technologies started to grow in number. In particular, the most significant patented inventions in the field seem to be issued by Procter & Gamble, processing the fragrances into cyclodextrin complexes. The general aim was to develop devices capable of slowly dispense fragrances to the surroundings in the long-term and replace the classic salt-based (sodium dodecyl benzene sulphonate) tablets with new, more practical and, let's say it, fancier house care solutions. The role of hydrogels in the process revolves around, once again, their swelling properties that can be exploited in materials "wherein release of a perfume smell is triggered by dynamic swelling force of the polymer when the polymer is wetted". These devices release volatile particles thanks to osmotic diffusion of the specie from the swollen hydrogel to new water in the environment.

Cosmetics

Hydrogels are prepared relatively small investment, companies are able to launch on the market new cosmetic products based on hydrogels, such as so called "beauty masks". Usually made with engineered collagen (Masqueology by SEPHORA USA Inc., BioCollagen Cosmeceuticals by NOVOSTRATA UK Ltd.), hyaluronic acid (SEPHORA USA Inc.), or polyvinyl pyrrolidone (Pecogel), these masks claim to hydrate the skin, restore its elasticity and promote anti-aging actions. Pecogels are suitable for cosmetic purposes, such as sunscreen cream or mascara. Furthermore, in some of the commercially available compounds such as Hydro Gel Face Masks by Fruit & Passion Boutiques Inc., the moisturizing action of these organic polymeric gels is coupled with more complex drug-delivery systems developed to release of biomolecules like vitamin C or

B3. The cosmetic industry is on the cutting edge of hydrogels, indeed a pH-Sensitive material P(MAA-co-EGMA) has been developed for release of cosmetics drugs like arbutin, adenosine, and niacinamide, well knowing molecules for wrinkle treatment and for skin-whitening.

Plastic Surgery

The hydrogel where seen as good materials for application in contact with the human body because of their extracellular matrix-like properties. This is the main reason why attempts were made to introduce hydrogels like new materials for plastic reconstruction. On this path, for many years, Hyaluronic Acid (HA) was thought like the panacea for every pain. One notable company operating in the field is Macrolane. Starting in 2008, Macrolane's treatments and products were specifically studied to enhance breast size and shape and offer a more biocompatible alternative to standard and aggressive silicone prosthesis. Thus nowadays Macrolane is used for diversely situated filling with the exception of breasts. The compound is injected inside the body with a syringe and let it gels restoring the volume. Another promising use of hydrogels is bulking agents for treatment of urinary incontinence: smart injectable gels can be involved in clinical procedures where these materials can be used to tighten the urethral channel and reduce patient's incontinence.

Environmental applications

Water pollution is one of the biggest issues afflicting especially poor areas, Thanks to their affinity for water, hydrogels might be used in two different ways to treat water source. First the matrix can be used as a holder for purifying microorganism. Many interesting studies, on this particular path, were developed by encapsulating microorganisms inside diverse carrier materials. Chlorella and Spirulina are the most used ones. These microorganisms are already used to remove pollutants chemicals from water resources. Both synthetic and natural hydrogels were been used. The best working hydrogels in literature appear to be Alginate derived or alternatively carrageenan and agar. A second interesting way to solve the problem of pollutants is to modify the hydrogels to let them seize and keep the pollutant inside the networks.

Bacterial culture

Hydrogels can hold inside their matrix a significant number of microorganisms for purification of water, for production of biomolecules, or for simple culture of bacteria by themselves. Indeed, agar is famous as the golden standard substrate for bacterial culture in biotechnological applications. Since it is indigestible by a great number of bacteria and microorganism, it provides a perfect environment for their culture on a solid substrate.

Electrophoresis and proteomic

Gel electrophoresis currently represents one of the most standard techniques for protein separation. In addition to the most commonly employed polyacrylamide cross linked hydrogels, acrylamide agarose copolymers have been proposed as promising systems for separation matrices in two dimensional (2-D) electrophoresis, because of the good resolution of both high and low molecular mass proteins made possible by careful control and optimization of the hydrogel pore structure. In particular, it is of great interest to investigate structure-property relationships of these hydrogels in the attempt to optimize their functional performance. A wide large range of hydrogel chemical compositions was studied and their effect on structural and functional properties of the hydrogel was elucidated. More specifically, the evaluation of the crosslinking density by means of dynamic tests and the use of viscoelastic models for determining the resistance of non-permanent crosslinks to move in the network systems shed light on the pore structure of the hydrogel matrix and helped to clarify its influence on the electrophoretic separation performance.

Applications in electronics

The use of hydrogels as matrixes in electronics is very promising considering the high tunability and precision of capacitors with hydrogel dielectrics. By changing the polymer and the solution carried it is possible to build high-performant cheap capacitors. These Hydrogel electrolytes can be composed by organic polymers. According to Choudhury et al., poly (ethylene oxide), potassium poly (acrylate), poly (vinyl alcohol) and gelatin are among the most promising materials for the purpose. However, organic polymer seems to show lower properties compared to the ones of inorganic hydrogels.

CURRENT RESEARCH ON HYDROGELS

Water Purification

Water Purification The ability to create clean, safe drinking water using only natural levels of sunlight and inexpensive gel technology could be at hand, thanks to an innovation in water purification. Engineers has developed a cost-effective and compact technology using combined gel polymer hybrid materials. Possessing both hydrophilic (attraction to water) qualities and semiconducting (solar-adsorbing) properties, these “hydrogels” (networks of polymer chains known for their high water absorbency) enable the production of clean, safe drinking water from any source, whether it’s from the oceans or contaminated supplies. The Texas Engineering researchers have developed a new hydrogel based solar vapor generator that uses ambient solar energy to power the evaporation of water for effective desalination. Existing solar steaming technologies used to treat saltwater involve a very costly process that relies on optical instruments to concentrate sunlight. The UT Austin team developed nanostructured gels that require far less

energy, only needing naturally occurring levels of ambient sunlight to run while also being capable of significantly increasing the volume of water that can be evaporated. "Water desalination through distillation is a common method for mass production of freshwater. However, current distillation technologies, such as multi-stage flash and multi effect distillation, require significant infrastructures and are quite energy-intensive; the hydrogels allow for water vapor to be generated under direct sunlight and then pumped to a condenser for freshwater delivery. The desalinating properties of these hydrogels were even tested on water samples from the salt-rich Dead Sea and passed with flying colors. Using water samples from one of the saltiest bodies of water on Earth, UT engineers were able to reduce salinity from Dead Sea samples significantly after putting them through the hydrogel process.[35]

Peptide hydrogel promotes tissue growth to heal without drugs

Rice university researcher studying how different drugs, proteins, and cells embedded in peptide hydrogel can boost healing and promote tissue formation discovered that hydrogel itself exhibit powerful therapeutic properties. Their self-assembling multidomain peptide (MDP) with amino acid sequence K2(SL)6K2 can be injected in to tissue to prove place for new cell to grow, the body eventually washing it way over a few weeks.in their studies, the rice team noted that the hydrogel promotes the formation of new blood vessels and attract nerve fibers, is inviting the host cells, and causes a short term inflammatory response, all surprising findings. The chemical composition of the peptide hydrogel and its physical structure play a role in its bioactive properties.[36, 37]

Hydrogel based capsule may help patient adhere to medication

Developed a new set of drug delivery called as an Ultra- log acting capsules, hydrogel material which can reside in the stomach for up to nine day, slowly releasing their dosage of medication. These capsules which might last for the entire course of treatment, or could be taken once a week or once a month, depending on device. Developing capsules that does not rapidly pass through the body, but can instead reside in the gastrointestinal tract for long periods of time, is no easy task, since may material must be able to withstand the consider able force in the stomach. Capsule made from the hydrogel in a hydrated state could be swallowed by the patient; they would be swell entering in the stomach, to prevent them passing through the pylorus, however hydrogel which are typically formed from a single network of crosslinking polymer chains, tend to be quit soft and they do not have a strength to withstand compressive forces. [38]

New stimuli responsive smart hydrogels open door to future material biology and biomedical applications

Hydrogels, also known as soft matter in the medical world, are leading materials for biomedical applications such as drug delivery and stem cell therapy. But traditional hydrogels, used in products such as facial masks and contact lenses, are made up of either synthetic polymers or biological extracts such as animal collagen, are likely to cause allergies. They cannot fully mimic the complex biological environment needed for cell growth and development. To create this novel hydrogel, the team assembled genetically engineered proteins into molecular networks by stitching together the photoreceptor C-terminal adenosyl cobalamin binding domain (CarHC) proteins at room temperature. The synthesis relies solely on bacterial culturing a process similar to fermentation. The composition of the resulting hydrogel resembles that of human tissues and thus can be used to deliver live cells into human bodies while potentially minimizing allergies and body rejection. As a drug carrier, this photo-responsive hydrogel can quickly switch from solid to liquid upon light exposure, thus allowing drugs to be released into the body in a controlled manner. The strategy of creating entirely protein-based hydrogels represents a new way to design bioactive materials with precise control over their properties.[39]

Multiamine-induced self-healing poly (Acrylic Acid) hydrogels with shape memory behavior

In this work, a versatile and simple strategy for building self-healing hydrogels with tunable mechanical properties and shape memory behavior is reported. A commercially available small molecule with three amino groups, diethylenetriamine (DETA), is applied to crosslink poly (acrylic acid) (PAAc) chains via ionic bonding, and the complexes of the PAAc chains with DETA form hydrophobic microdomains in the hydrogel network. The cooperation of ionic bonding and hydrophobic interactions drastically improves the mechanical properties, which can be modulated by adjusting the molar ratio of PAAc to DETA. Due to the physical interaction of the crosslinks, the hydrogels can self-heal rapidly in ambient conditions. The thermal responsiveness of the physical microdomain crosslinks the hydrogels with shape memory behavior. It is hoped that this novel strategy will provide new opportunities for the design of high-strength hydrogels with variable functionalities for a wide range of applications, such as artificial muscle and skin.[40]

Newly developed hydrogels may pave way for novel eye surgery techniques

A newly developed elastic gel administered in liquid form shoe to tern jelly like within minutes after injection into rabbits eye to replace the clear gelatinous fluid inside the eyeballs, may help pave the way for new eye surgery techniques.

Plant-Based Hydrogels: Applications in Cosmetics

Hydrogels are hydrophilic polymeric structures that can be cross-linked through various methods. They are widely used in cosmetics and skin preparation products and can be formed from

polysaccharides found in natural plants. Here, the main categories of polysaccharides and related products used in the cosmetics industry. The unique properties of polymeric hydrogels including biocompatibility, high water content, elasticity and softness have drawn the attention of scientists in the context of skin preparations. Naturally derived hydrogels are usually based on protein chains or polysaccharides formed by single sugar molecules linked together. The chemical industry is making huge efforts to modify polysaccharide structures and produce refined materials with specific properties. As such, here, the main sources of plant-based hydrogels.[41]

Recent Advances in Hydrogel-Based Drug Delivery for Melanoma Cancer Therapy

The latest advances in using hydrogels for cancer melanoma therapy. Hydrogel formulations of polymeric material from natural or synthetic sources combined with therapeutic agents have gained great attention in the recent years for treating various maladies. These formulations can be categorized according to the strategies that induce cancer cell death in melanoma. First of all, we should note that these formulations can only play a supporting role that releases bioactive agents against cancer cells rather than the main role. This strategy involves delivering the drug via transdermal pathways, resulting in the death of cancerous cells. Another strategy utilizes magnetic gel composites to combat melanoma via hyperthermia therapy.[42]

CONCLUSION

Hydrogel based delivery devices can be used for oral, ocular, epidermal, subcutaneous application due to their high water contents and soft consistency hydrogels resemble natural living tissue more than any other class of synthetic biomaterials. Recently, many hydrogel based networks have been designed and personalized to meet the needs of different applications. When putted in contact with an aqueous solution these hydrogels is either ability to swell. The present review demonstrates about the classification of hydrogels on different bases, physical and chemical characteristics and technical feasibility of their utilization, method of preparation and application. There are present various methods by which hydrogels can be prepared. Some of them are discussed in this article.

ACKNOWLEDGEMENT:

Authors are thankful to management and Principal of Loknete Dr. J. D. Pawar, College of Pharmacy, Manur, Kalwan, Dist. - Nashik, Maharashtra for their constant support and providing facilities.

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