International Journal of Medical and Pharmaceutical Research
Website: https://ijmpr.in/ | Print ISSN: 2958-3675 | Online ISSN: 2958-3683
NLM ID: 9918523075206676
Volume: 4, Special Issue:3 (May-June 2023); Page No: 42-50

Review Article

IJMPR

Formulation and Evaluation of Hydrogel

Shreya Jaiswal[*1]; Dr. Jyoti Rai[1]; Dr. J.Narayan Mishra[1]

[1]Kailash Institiute of Pharmacy and Management, Gida, Gorakhpur

ABSTRACT

Hydrogels are a class of materials that have gained widespread attention in recent years due to their unique physical and chemical properties, as well as their potential for use in a variety of applications. A Hydrogel is three dimensional network of cross linked polymers that is capable of swelling in water, resulting in a soft gel –like material that can be used for a variety of purposes. Hydrogels are three-dimnensional polymer networks that can be absorb and retained large amounts of water. They have gained widespread attention due to their unique properties, including high water content, biocompatibility, and biodegradability. Hydrogels can be synthesized from a wide range of polymers, including natural and synthetic polymers.

Key Words: *Hydrogel ,biodegradability, biocompatibility, polymers, cross-linked*

***Corresponding Author**
Shreya Jaiswal
Kailash Institiute of Pharmacy and Management, Gida, Gorakhpur

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 aqeous media thus forming hydrogel structure. Generally it is based on the chemical composition which is responsive to the various stimuli such as heating, PH, Light, and chemicals. Hydrogels can also prospect by rheological manner and swollen polymer network which flatter hydrated in the liquid media that reffered to as the hydrogel structure. Many theories are involved in the in swelling mechanism such as Equilibrium swelling theory, Rubber elastic theory, Mechanism of gelation and calculation of mesh size.

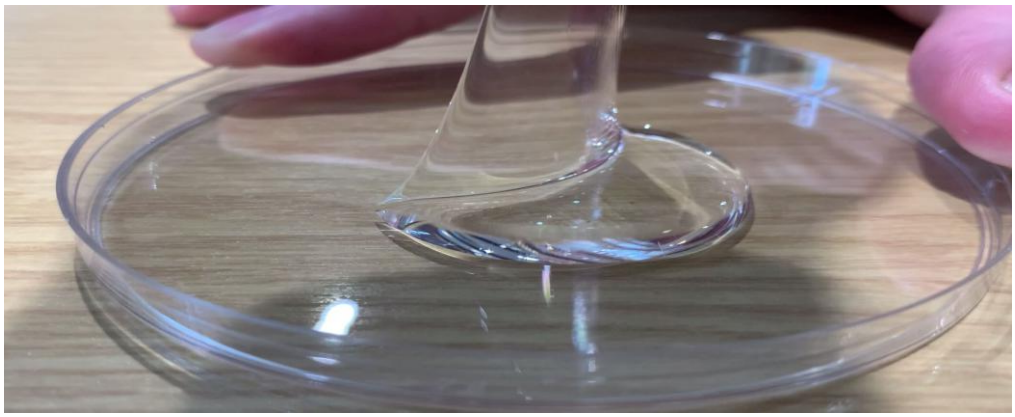

Figure 1: Structure Of Hydrogels

Types of Hydrogels:-

Hydrogel can be classified based on their origin, chemical structure, and physical properties. The three primary types of hydrogels are:

1.Natural hydrogels:- These are hydrogels that are derived from natural sources ,such as collagen, gelatin, chitosan and hyaluronic acid. These hydrogels are biocompatible and their properties can be easily modified by changing the source of the natural polymer.

2. Synthetic hydrogels:- These are hydrogels that are synthesized from synthetic polymer such as poly(ethylene glycol) (PEG), Poly(vinyl alcohol)(PVA) and poly (acrylic acid) (PAA). These hydrogels are highly tunable, and their properties can be tailored or suit specific applications.
3. Semi-synthetic hydrogels:-These are hydrogels that are synthesized from a combination of natural and synthetic polymers. Examples include alginate, which is derived from seaweed, and is v often combined with synthetic polymers.

Advantages

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 [1]

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: [2]

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[3].

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[4].

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[5].

CLASSIFICATION OF HYDROGEL PRODUCTS

Hydrogel can be classified on different bases as detailed below:

I. Classification based on source [6]

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 [7]

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 naturalpolymer 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[8]

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 [9]**

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 [8]**

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.

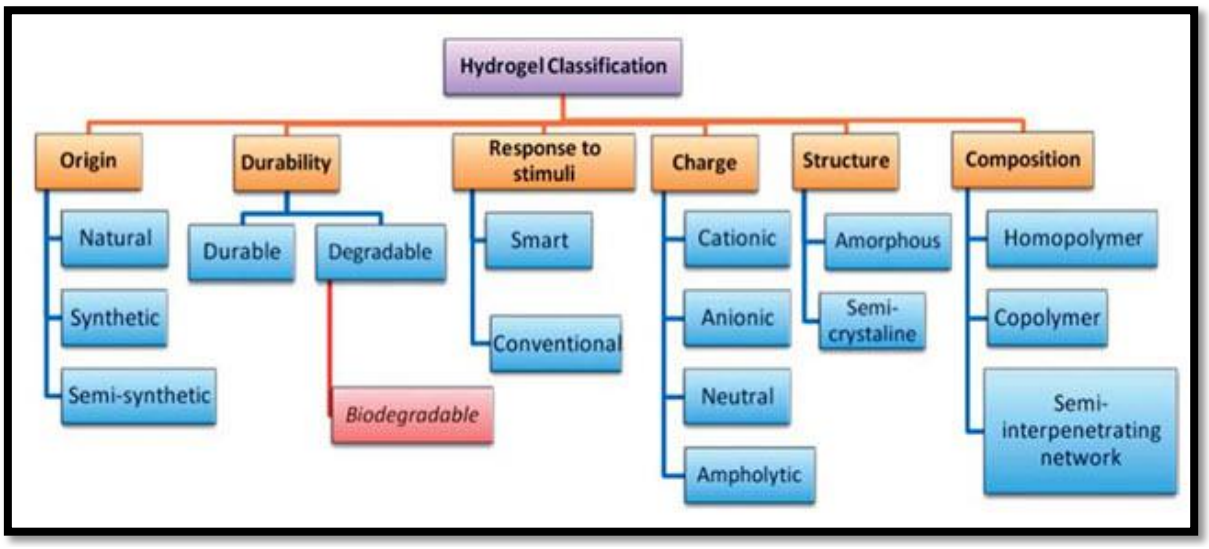

Figure 2: Flow chart of Hydrogel Classification.[10]

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[11].

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[12].

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[13].

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[14].

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[15].

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 crosslinked structure is formed[16].

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.

DRUG RELEASE MECHANISM

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. Chemically-controlled release can be further categorized according to the type of chemical reaction occurring during drug release. Generally, the liberation of encapsulated or tethered drugs can occur through the degradation of pendant chains or during surface erosion or bulk-degradation of the polymer backbone**.**

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 hydrogels.

CHARACTERISTICS OF HYDROGELS

Morphological Characterization:

Hydrogels are characterized for morphology which is analysed by equipment like stereomicroscope. Also the texture of these biomaterials is analysed by scanning electron microscope to ensure that hydrogels, especially of starch, retain their granular structure [11].

Rheology:

Hydrogels are evaluated for viscosity under constant temperature of usually 4^{o}c by using Cone Plate type viscometer. This viscometer is highly specific for the evaluation of viscosity. The viscosity is determined by the simple equation of determining the angle of repose through that height and length.

X-ray diffraction:

Diffraction analysis is the estimation of crystalline or amorphous characteristics. The appearance of new peaks in powder pattern is characteristic of drug - excipient interaction. X-ray diffraction is particularly used for the determination of broad halos that is a characteristic of impurities in powder that determines the pattern of the arrangement in which the hydrogel layers are distributed.

Light scattering:

Gel permeation chromatography coupled on line to a multi angle laser light scattering (GPCMALLS) is a widely used technique to determine the molecular distribution and parameters of a polymeric system. Hydrogel in a polymeric system can be quantified using this technique. This technique is widely used in quantifying the hydrogels of several

hydrocolloids such as gum arabic, gelatin and pullulan. It can be demonstrated how mass recovery data obtained from GPC-MALLS correlate with actual amount of hydrogel obtained for dextran radiation in solid state[12].

***In-Vitro* Diffraction:**

The *in-vitro* diffraction study is quite popular for studying the release profile of hydrogel. One that basis the bioequivalence study is carried out to estimate the release of dosage forms. The parameters are matched with the standard plot so that the equivalence between the drug solution is carried out. *In-vitro* diffraction of type-1 collagen hydrogel containing bioactive glass and silica sol-gel micromeritics particles are formulated and their*in-vitro* apatite forming ability have been simulated by body fluids that is assessed.

Fourier Transform Infrared Spectroscopy:

Any change in the morphology of hydrogels changes their IR absorption spectra due to stretching and O-H vibration. Formation of coil or helix which is indicative of cross linking is evident by appearance of bonds near 1648cm-1. The stretching or bending vibrations are basically responsible for the changes in IR absorption spectra. FTIR is an easy way to identify the presence of certain functional groups in a molecule. Also one can use the unique collection of absorption bands to confirm the identity of a pure compound or to detect the presence of certain impurities.

Swelling measurement

The swelling measurement of hydrogel was carried out as follows. Pieces of xerogel were immersed into 250 ml distilled water. The samples of swollen hydrogel were weighed after removal of surface water using filter paper at designed time intervals. Data presented in this experiment were the mean values of triplicate measurements. Results were calculated according to the following equation:

$$[Q= W_s/W_d]$$

Where Ws is the mass of the hydrogel in the swollen state, Wd is the mass of the hydrogel in the dried state and Q is equilibrium swelling ratio.

Scanning Electron Microscopy:

SEM can be used to provide information about the sample's surface topography, composition, and other properties such as electrical conductivity. Magnification in SEM can be controlled over a range of up to 6 orders of magnitude from about 10 to 500,000 times. This is a powerful technique widely used to capture the characteristic 'network' structure in hydrogels[13,14].

HYDROGELS TEST

Water Vapour Transmission Rate:

Water vapour transmission rate (WVTR) is defined as the quantity of the water vapour under specified temperature and humidity conditions, which passes through unit area of film material in fixed time. Water vapour transmission rate is measured in grams per square meter over a 25 hours period. It is inversely proportional to the moisture retentive nature of a wound dressing i.e the wound dressing with lower water vapour transmission rate will be able to retain wound surface moisture. Typically, a wound dressing material showing WVTR less than 35g/m2/hr is defined as moisture retentive and helps in a rapid healing.

Biocompatibility Test:

Generally hydrogels are biocompatible and non-irritant in nature. In this method, the material whose biocompatibility has to be determined is placed in direct contact with the host environmental cells and is subsequently incubated for a specific period of time at 37^{o}c. In the second method, the material is placed in a suitable physiological solution and is incubated for a specific period of time at 37^{o}c to allow any leaching from the material. The leachates, so obtained, are used to carry out the biocompatibility tests in the presence of cells.

APPLICATIONS

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. The diisocyanate that is proposed for the equilibrium degree of mechanical strength[15].

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.

Modified Dosage Forms: An interesting research in the field of drug delivery is of bio- macromolecules like insulin delivered to the site of absorption with hydrogels of poly (methacrylamide co - itaconic acid)[16].

Rectal Delivery – hydrogels showing bioadhesive properties are used for recatal drug delivery.

Potein drug delivery – hydrogels which show better complicance and form in situ polymeric network and release protein slowly.

Transdermal delivery – hydrogels can be used as controlled release devices in the filed of wound dressing due to it swelling properties. Hydrogel based formulations are being explored for transdermal iontophoresis to obtain enhanced permeation of products.
Subcutaneous delivery – anticancer drugs are mainly used for the subcutaneous delivery. Implantable vegetable are now leading towards the development of biodegradable system which don't require surgical removal once the drug administered.

Cosmetology – hydrogels when implanted into breast accentuate them for aesthetic reason. These implants has silicon elastomer shell and are filled with hydroxyl propyl cellulose polysaccharide gels.

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 or acquired diseases.

Wound healing – modified polysaccharide found in cartilage is used in formation of hydrogels to treat cartilage defects. For example, the hydrogel of gelatin and polyvinyl alcohol together with blood coagulants are formulated.

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.

Tropical drug delivery – instead of conventional creams, hydrogels formulation are employed to deliver active components like desonide, a synthetic corticosteroids used as an anti – inflammatory for better patient compliance.

CHALLENGES OF HYDROGEL DEVICES

There are still many challenges associated with the modeling of drug delivery phenomena and release profiles related to complex hydrogel systems. Fundamental understanding of drug transport processes helps in developing a suitable mathematical model. Mass transport governs the translocation of drug from the interior to the surrounding environment of hydrogel devices. Factors affecting mass transport of encapsulated molecules are as Follows:

1. Network cross linking density
2. Extent of swelling
3. Gel degradation
4. Size and charge of the encapsulated molecules⎫
5. Physical interactions between the encapsulated molecules and the polymer matrix
6. Drug – ligand binding present within hydrogel device

A. Dynamic Hydrogel Delivery Devices

Degradable hydrogels – Rate of matrix swelling and degradation mechanism govern the diffusion of encapsulated molecules. With the help of appropriate design of polymer chemistries and network structure, degradable hydrogel matrices are enabled with proper degradation profiles. Mathematical modeling has enriched us with sufficient information to facilitate the design of degradable hydrogels and identify critical parameters dictating molecule release profiles. Stimuli sensitive hydrogels This advanced hydrogel system detects changes in complex in vivo environments and utilize such triggers to modify drug release rates. As the swelling or deswelling of such hydrogels is mediated by external stimuli, it is critical to model the dynamic swelling response in order to predict solute release

B . Composite Hydrogel Delivery Devices b It has been exhausted for delivering multiple protein therapeutics for tissue engineering applications where temporal and spatial control over drug delivery is desirable. It is of two types which are listed below

- Multilayer
- Multiphase

Examples of in-vivo simultaneous delivery of multiple proteins is – angiogenesis, bone remodeling and nerve regeneration.

Multilayer hydrogel devices

The system comprises of a basal polymer layer, followed by lamination of subsequent layer. Different proteins are encapsulated into each layer while fabrication and tunable multiple protein release or unique single-protein release approach are made possible by independently adjusting the cross-linking density of each layer. Various models have been developed for predicting drug release from multilayer hydrogel devices 52. It employs Fick's second law of diffusion to predict drug release profiles 53. Sohier et al. have developed a porous scaffold bearing three hydrogel layers with differing porosities to simultaneously deliver lysozyme and myoglobin. These devices can also be used to reduce the problem of burst release. A desirable zero-order release profile was achieved through non-uniform initial drug loading in multi-laminated hydrogels and the results were verified by a diffusion model.

Multi-phase hydrogel delivery devices

Prefabricated microspheres possessing one or more proteins are uniformly embedded within a hydrogel having a second protein57-59. The release of the protein encapsulated in microsphere is delayed due to the combined diffusional resistances of the microsphere polymer and surrounding gel. Richardson and colleagues have prepared a composite polymeric scaffold containing PLGA microspheres embedded in porous PLGA matrices with different intrinsic viscosities to simultaneously deliver VEGF and PDGF. It was the first heterogeneous polymeric system for delivering two proteins with distinct release profiles which can be adjusted by varying the protein loaded in each polymer phase.

Micro/ nanoscaled hydrogel devices Mathematical approaches proposed to predict molecule release from hydrogel microspheres are of two types viz. Macroscopic diffusion models• Microscopic Monte carlo simulations• For macroscopic modeling, models used are based on Fick's second law of diffusion. Particle size, geometry and surface area are important parameters in this type of modeling. Further molecule diffusivities must be considered and accurately determined 60. Monte carlo simulation is useful for describing the transport behaviour of molecules with in degradable microsphere system and has been widely applied to hydrophobic polymer networks viz. PLGA61,62. Vlugt wensink et al. utilized this model to predict protein release from degradable dextran microspheres. However, the accuracy of the model is protein specific63. One of the disadvantages of this technique is burst release due to the high surface to volume ratio of this particulate systems which causes "dose dumping" effect and is potentially harmful to patients in clinical applications

IN- SITU HYDROGELS

Recent advancement in hydrogel engineering has led to the development of in-situ hydrogel formation for drug delivery applications. The in-situ sol-gel transition enables the surgery or implantation procedure to be performed in a minimally invasive manner. Various physical and/or chemical cross linking mechanisms have been used for insitu network formation. Physical phenomenon involved in the formation of in-situ hydrogels are as follows

- ✓ Hydrogen bonding
- ✓ Hydrophobic – hydrophobic interactions.
- ✓ Electrostatic interactions.

For example, sodium alginate hydrogels are formed physically by cross-linking due to addition of calcium ions but are unstable and disintegrate rapidly and unpredictably

Chemical cross linking mechanism – Covalent cross linking methods performed under physiological conditions produce relatively stable hydrogel networks with predictable degradation behavior. For example, photo polymerization of multi- vinyl macromers. It is a fast process and can be conducted at room temperature without organic solvents65. Photo polymerization of degradable hydrogels may be applied to protein and gene delivery66, 67. Van de Wetering et al. identified the modification of hGH by reactive thiol macromers in PEG-based hydrogel system prepared by Michael type addition reaction. Quick and Anseth identified that free radicals are responsible for incomplete DNA release when photo polymerization was used to fabricate DNA fabricated hydroge

CONCLUSION

Hydrogels have played a significant role in biomedical applications. Significant progress has been made in improving the properties of hydrogels used for drug delivery and expanding the range of drugs and kinetics which can be achieved using a hydrogel based delivery vehicle. Reduced release efficiency, burst effects, complex geometries and unknown correlation between in vitro and in vivo release complicates our understanding of these devices.

There is need for continued improvement in the delivery of not only hydrophobic molecules, but also the delivery of more sensitive molecules viz. proteins, antibodies or nucleic acids which gets deactivated by interactions with the hydrogel delivery vehicle. Solution of such problems would greatly expand the potential of hydrogel based drug delivery to successfully deliver the next generation drugs at the desired rate and location in the body.

REFERENCE

1. Mohite PB, Adhav SS(2017). A hydrogels: Method of Preparation and applications. International Journal of Advances in Pharmaceutics; 06(03):79-85.
2. Pande PP, Anamica(2017). Polymer Hydrogels and Their Applications. International journal of materials science; 12(1): 0973-4589.
3. Das N(2013). Preparation Methods and Properties: a review. International Journal of Pharmacy and Pharmaceutical Sciences; 5(3):0975-1491.
4. Chirani N, Yahia LH, Gritsch L. et al(2016). History and Applications of Hydrogels. Journal of Biomedical Science; 4:2.
5. Garg S, Garg A(2016). Hydrogel: classification, Properties, Preparation and Technical Features. Asian Journal of Biomaterial Research; 2(6):163-170.

6. Devi A, Nautiyal U, Kaur S, Komal(2014). Hydrogel: a smart drug delivery device. Asian Pacific Journal of Health Sciences; 1(4S): 92-105.
7. Shetye SP, Dr. Godbole A, Dr. Bhilegaokar S, Gajare P(2015). Hydrogels: Introduction, Preparation, Characterization and Applications. International Journal of Research Methodology; 1(1)
8. Meshram PS, Kale SD, Labale PS, Mate KS(2017). Hydrogel Polymer: A Unique Material for Bio-Separation, Bio-Sensing and Drug Delivery. International Advanced Research Journal in Science, Engineering and Technology; 4(3).
9. Sing A, Sharma PK, Garg VK, Garg G(2010). Hydrogels: a review. International journal of Pharmaceutical Sciences Review and Research, 4(2).
10. Saini K(2016), Preparation method, Properties and crosslinking of hydrogel: a review. PharmaTutor; 5(1): 27-36.
11. Sing SK, Dhyani A, Juyal D(2017). Hydrogels: Preparation, characterization and Applications. The Pharma Innovation journal; 6(6): 25-32.
12. El-Sherbiny IM, Yacoub MH(2013). Hydrogel scaffolds for tissue engineering: Progress and challenges. Global Cardiology Science and Practice; 38.
13. Thakur VK, Thakur MK, Kessler MR(2017). Handbook of Composites from Renewable Materials, Polymeric Composites. Scrivener Publishing.Vol.6.
14. Dwivedi S, Khatri P, Mehra GR, Kumar V(2011). Hydrogel- A conceptual overview. International Journal of Pharmaceutical & Biological Archives; 2(6): 1588-1597.
15. Bhosale RR, Osummani RA, Ghodake PP, Shaikh SM ,Chavan SR(2013). Thermosensitive Hydrogel: an inventive carrier for drug delivery. International Journal of Pharmaceutical and Medicinal Research; 1(2): 60-69. 2
16. Siddeswara M, Purushothaman M, Kumar MP, Raja MS, Yasmin S, Swathi R(2016). Formulation and Evaluation of Desvenlafoxacine Succinate Hydrogel. International Journal of Current Trends in Pharmaceutical Research; 4(5).