A REVIEW ARTICLE ON HYDROGELS

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ABSTRACT

Hydrogel is a 3D network of polymer chains that can absorb a large amount of water. It is one of the first biomaterials to be used for human use, and it has been used for a long time in medical applications such as wound healing, controlled drug delivery, and tissue engineering. It is also used in manufacturing contact lenses and hygiene products, and it can be either chemically stable or degraded. It is biodegradable, which has attracted a lot of interest in drug delivery systems, and it has some really cool biometric properties. It is flexible, soft, has a lot of absorption, is

biocompatible, and is biodegradable. Over the last 60 years, it has been used to make implants, injectables, and sprays for many organs and tissues, and it can swell in aqueous conditions without dissolving.Hydrogels are a type of material that has been around since the beginning of time. They are usually biocompatible and can be used as a liquid to be injected into the body. Initially, people knew about hydrogels and used them for various purposes. Nowadays, synthetic polymers are the go-to for hydrogels because of their purity, high absorption, well-structured, and well-defined functions, as well as their ability to degrade and remain stable in different pHs, temperatures, pressures, and enzymes. More recently, researchers have focused on hydrogels that react with biological conditions.

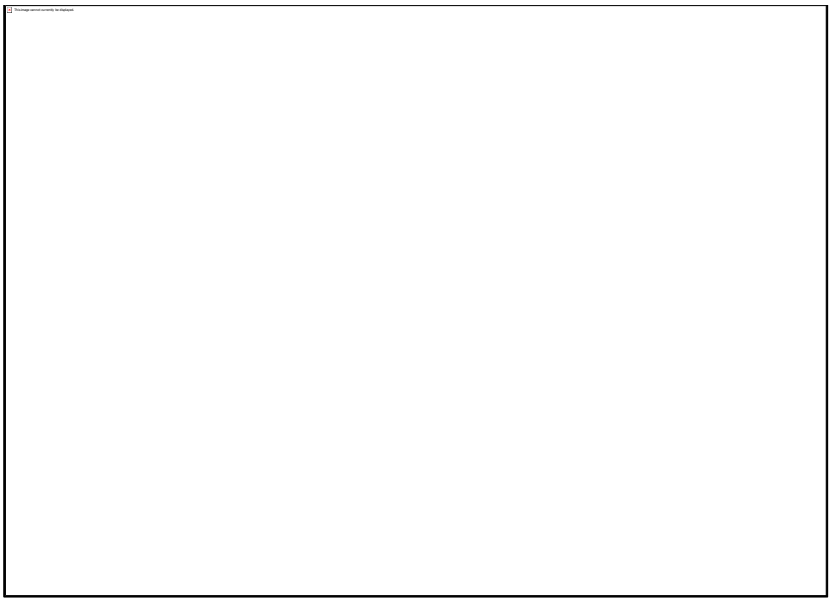

Figure.1. hydrogel

KEYWORDS

Biodegradable, Polymerization, Crosslinked networks, Swelling, Hydrogels.

INTRODUCTION

Biomaterials have been extensively studied in the field of human health, with hydrogels being one of the most prominent research topics. Hydrogels are three-dimensional, water-soluble networks of polymer molecules that are capable of absorbing large amounts of fluid or water from the body because of their hydrophilic structure. These hydrogels are composed of hydroxyl, carboxyl, amine, and sulfate groups, and can be formed through physical crosslinking, chemical crosslinking, or a combination of the two. The chemical structure, morphology, and equilibrium swelling of a hydrogel influence its mechanical strength and its ability to transport intracellular and extracellular fluid.Hydrogels are created from a variety of sources, including natural or synthetic polymer structures, homopolymer networks, copolymer networks, and permeable networks. Physical and chemical cross-links are used to create three-dimensional structures of hydrogels that are capable of trapping and releasing therapeutic agents such as drugs and biomolecules. Injectable hydrogel, also known as injectable hydrogel, is used in systems where the polymer solution is introduced

into the body as a liquid and converted into a solid hydrogel through the use of physical and chemical cross-linking agents. Factors such as temperature, pH, ionization, heat, and solvent resistance are all involved in the cross-linking process. Recently, researchers have focused more attention on hydrogels that can respond to biological conditions.

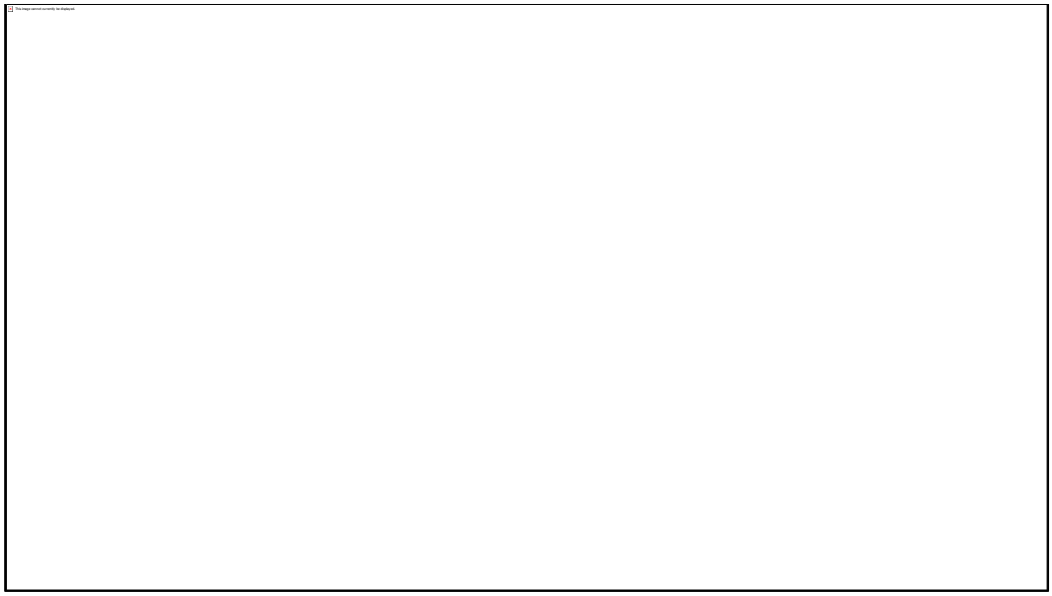

Figure.2. Hydrogel

LIMITATIONS

- High cost.
- Low mechanical strength.
- Difficult to load.
- Difficult to sterilize.
- Non-adherent.
- In contact lenses - lens deposition,hypoxia, dehydration and red eye reactions.

ADVANTAGES

- Hydrogels are biocompatible.
- Modification is easy.
- Hydrogels have also demonstrated high transport efficiency.
- The release of growth factors and other nutrients occurs at predetermined intervals to ensure optimal tissue development.
- Microbial cells entrapped within the polyurethane hydrogel beads, which have low toxicity.
- Environmentally sensitive hydrogels can detect changes in pH, temperature, or metabolite concentration and release their load as a response to change.

DISADVANTAGES

- Hydrogels are expensive.

- They are non-adherent and may need to be secured by secondary dressing and also cause sensations felt by movement of the maggot.
- Difficult to sterilize.
- Hydrogels used as contact lenses cause lens deposition, hypoxia, dehydration and red eye reactions.
- Difficulty in handling.
- Difficulty in loading.

CLASSIFICATION OF HYDROGEL PRODUCTS

Hydrogel products can be classified according to various criteria, as outlined below.

I. Classification based on the source

Hydrogels can be classified into two groups based on their natural or synthetic origins.

a. Natural hydrogels:
Natural hydrogels possess a range of desirable characteristics, including biodegradability, biocompatibility, and excellent cell adhesion. Two primary types of natural polymers are used to create natural hydrogels: proteins, such as collagen, gelatin, and lysozyme, and polysaccharides, such as hyaluronic acid, alginate, and chitosan.

b. Synthetic hydrogels:
Synthetic hydrogels are more advantageous than natural hydrogels due to their ability to be designed to possess a greater variety of mechanical and chemical characteristics than their counterparts. PEG-based hydrogels are among the most commonly used materials in biomedical applications because of their lack of compatibility and lack of immunogenicity.

c. Hybrid hydrogels:
Hybrid hydrogels are a combination of synthetic and natural polymer hydrogels that combine the benefits of both natural and synthetic hydrogels. Examples of natural biopolymers that have been used in hybrid hydrogels include dextran, collagen, and chitosan. Synthetic polymers have also been used in these hybrid hydrogels, such as poly(N-isopropylamide), polyvinyl alcohol, and others .

II. Classification according to the polymeric composition

a. Homopolymeric hydrogels:
Homopolymeric hydrophilic materials are fundamental structural units composed of any type of monomer-derived polymer network, and may, depending on the type of monomer and the polymerization technique used, have cross-linkable skeletal structures. To prepare homopolymers, a film was prepared using polyethylene glycol dimethyl dimethyl acetate as a cross-linker, poly ethylene methyl ethyl ether as a monomer, and a UV-sensitive initiator. Subsequently, the film was immersed in water for a period of 24 h until it was completely saturated, to eliminate any toxic or unreactive substances that could harm living tissue. In addition to contact lenses, homopolymers are also used in the production of artificial skin and in the production of burn dressings to ensure good wound healing conditions. In addition, they are used for the regeneration of bone marrow, spinal cord cells, scaffolds to promote cell adhesion, and the production of artificial cartilage.

b. Copolymeric hydrogels:

Copolymer hydrogels are composed of two or more distinct monomer species with a minimum of one hydrophilic component each, arranged in a block or alternating arrangement, randomly along the polymer network chain. These hydrogels are synthesized by polymerizing BLG N-carboxyanhydride with diamine groups at the ends of the poly(ethylene oxide) and poloxamer chains.They are characterized by their pH and temperature sensitivity, making them suitable for drug delivery applications.

c. Multipolymer interpenetrating polymeric hydrogel:
Multipolymer interpenetrating polymer hydrogel (IPN) is a type of hydrogel that has a network system composed of two separate, cross-linked, synthetic or natural polymer components, one of which is cross-linked and the other is uncrossed. The semi-IPN hydrogel is composed of one component with a cross-link and one component without a cross-link, allowing thermodynamic compatibility to be overcome. In addition, the IPN method is capable of achieving limited phase separation due to the permanent interlock of network segments. The cross-linked structure of IPN is believed to provide stability to the bulk composition and surface morphology.

III. According to the biodegradability

a. Biodegradable hydrogels:
Biodegradable hydrogels are composed of various natural polymers. Examples of naturally occurring polymers that are biodegradable include chitosane, fibrin and agar. Additionally, Poly(aldehyde-guluronate) and polyanhydrides, and N-isopropyl Acrylamide (N-isopropyl), are examples of synthetic biodegradable polymers.

b. Non-biodegradable hydrogels:
Vinylated monomers and macromers are commonly used in the production of non-biodegradable hydrogels. Examples of these monomers include 2-Hydroxyethyl methacrylic acid (HEMA), methamphetamine polyethylene glycol, 2-Hydroxypropyl methacrylamide, 2-hydroxypropyl methyl methacrylic acid, acrylamide, and ethylene glycol.

IV. Classification based on the configuration
Hydrogels are classified according to their physical structure, with their chemical composition as follows:
a. Amorphous (non-crystalline).
b. Semicrystalline: A complex mixture of amorphous and crystalline phases.
c. Crystalline

V. Classification based on the type of cross-linking:
Hydrogels can be classified according to the chemical or physical properties of the cross-linked junctions.
a. Chemically cross-linked networks have permanent junctions.
b.The entanglement of polymer chains creates transient junctions in physical networks

VI. Classification based on physical appearance
The appearance of hydrogels as a matrix, film or microsphere depends on the polymerization process used in the preparation.

VII. Classification according to the network electrical charge
Hydrogels can be classified into four categories based on the presence or absence of an electrical charge on the cross-linked chains:

a. Nonionic (neutral).
b. Ionic (including anionic or cationic).
c. Amphoteric electrolyte (ampholytic) containing both acidic and basic groups.
d. Zwitter ionic (polybetainees) containing both anionic and cationic groups

METHOD OF PREPARATION

To customize the properties of a hydrogel for a particular application, hydrophilic and hydrophobic molecules are sometimes employed in preparation. Several techniques are employed in the formulation of hydrogels, which can be prepared using either synthetic or natural polymers. Synthetic polymers are more hydrophobic than natural polymers and are also more chemically robust. Because of their mechanical strength, the decomposition rate is slower, however, mechanical strength also increases the durability of the product. Generally, the components of hydrogel formulation include monomers, initiators and cross-linking. The general steps for the production of physical and chemical gels can be found below.

1. Emulsion cross-linking

SPM operations involve the combination of ionic (or neutral) monomers with a multifunctional cross-linking agent. The polymerization process is initiated by UV irradiation or the use of a redox initiator system. The primary benefit of solution polymerization over bulk polymerization is the presence of a solvent, which serves as a heat sink . To purify the hydrogels produced by washing and rinsing them with distilled water, when the quantity of water used During the polymerization process exceeds the quantity used During the bulk polymerization process, phase separation occurs, resulting in the formation of heterogeneous hydrogels.

The research team at Rokhade Apet al. developed and evaluated a hydrogel microsurgery containing chitosan(CS) and Pluronic F127(PF-127) using an emulsion-cross-linking method with glutaraldehyde(GA) as a crosslinker. The anticancer drug 5-FU, was encapsulated in the microsurgery. The formulation was prepared by varying the ratio of CS to F-127, the percentage of drug loading, and the amount of GA. According to SEM, the microsurgery had a smooth, shiny surface. UV spectroscopy was used to measure the encapsulation of the drug, which was achieved at a rate of up to 86%. In vitro release studies revealed a relationship between the release rate and the extent of cross-linking. The data were then fed into an empirical equation to calculate the diffusional exponent (n), indicating that the release mechanism followed a non-fickian trend. F12 was chosen as the optimal formulation for maximum encapsulation efficiency.

2. Free radical polymerization

Free radical polymerization is a chemical process in which a range of monomers are used to form polymers. These monomers may be functionalized with radicalizable groups or contain appropriate functional groups. During the initiation phase, radicals are generated from the monomers and react with them to form active forms. Heaters, ultraviolet , visible , redox , and various other initiators are employed to generate radicals. In one example of free radical polymerization, fabricated hydrogels using a reaction vessel constructed with a jacketed shell and a constant flow of nitrogen. This reaction was initiated using C(+)ammonium nitrate. The resulting polymers were grafts of guar (g-poly) and acrylamide (acrylic).

The graft copolymer was evaluated using FTIR, TGA and SEM. The SEM analyzes indicated that the microbeads containing PAAM-GAM/Sodium Alginate were virtually spherical in shape. The largest swelling index was observed in the phosphate buffer at pH 7.4, while the lowest index was observed at pH 9.2 . The release of doxofylline was controlled as the polyacrylic acid content of the copolymer increased and the sodium alcohol content of the microbeads decreased, with a larger release in the medium at pH 7.4 compared with the medium of pH 1.2.

3. Bulk polymerization

Polymerized hydrogels may be produced using one or more monomers, with vinyl monomers being the most commonly used for the formation of bulk hydrogels. For most hydrogel forms, a minimal amount of cross-laminating agent is employed. The polymerization reaction is initiated by irradiation, ultraviolet light or chemical catalysts, and the choice of an appropriate initiator depends on the types of monomers and solvents employed. The various forms of polymerized hydrogels produced by this method include rods, particles, membrane emulsions, and films.

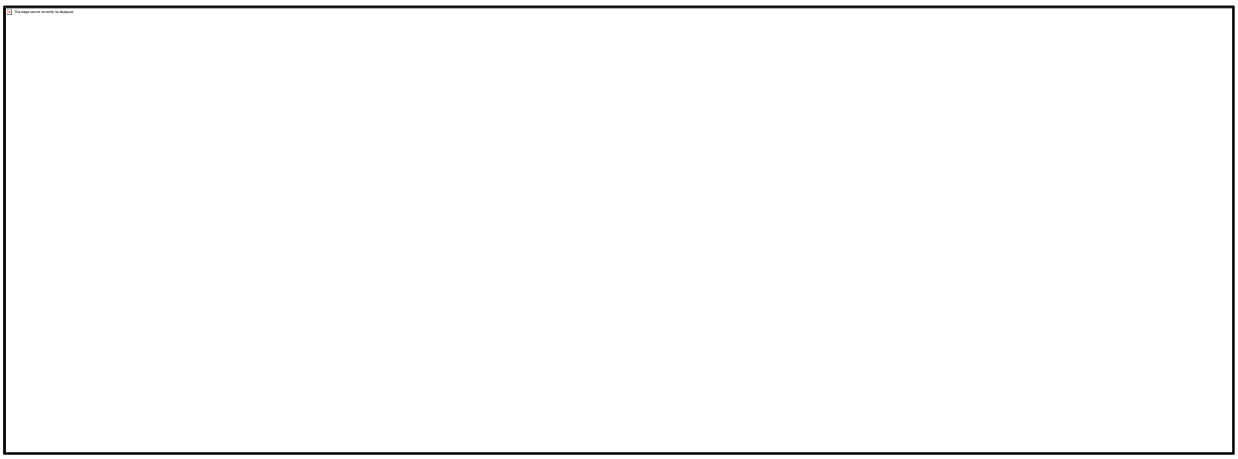

Figure.3. Schematic diagram of hydrogel preparation

4. Solution polymerization

Neutral monomers or ionic monomers are combined with a multifunctional crosslinking agent. UV-light or a redox initiator framework are used to begin polymerization. Solution polymerization has a significant advantage over bulk polymerization because of the solvent's role as a heat sink. The dissolvable monomers, initiator, cross-connecting specialist, oligomers, extractable polymer, and different impurities were washed out of the delivered hydrogels using refined water. Solvents included water, ethanol, benzyl alcohol, and water–ethanol blends. Ahmed S et al. using chitosan-based hydrogel membranes, [43] developed and characterized topical membranes for treating bacterial skin infections. Alterations to the free extreme arrangement polymerization process were used to form the polymeric layers. High-molecular-weight chitosan polymer and monomer 2-acrylamido-2-methylpropane sulfonic acid were cross-linked using the cross-linker N,N-methylenebisacrylamide. As an example, the antibiotic mupirocin was used. Swelling behavior, drug release,the irritation study,and ex vivo drug permeation and deposition studies were used to characterize hydrogel membranes. Up to 104.09 g cm 2 h-1 was the permeation flux. Furthermore, critical maintenance of medications in the skin up to 2185μg 1.5 cm−2.

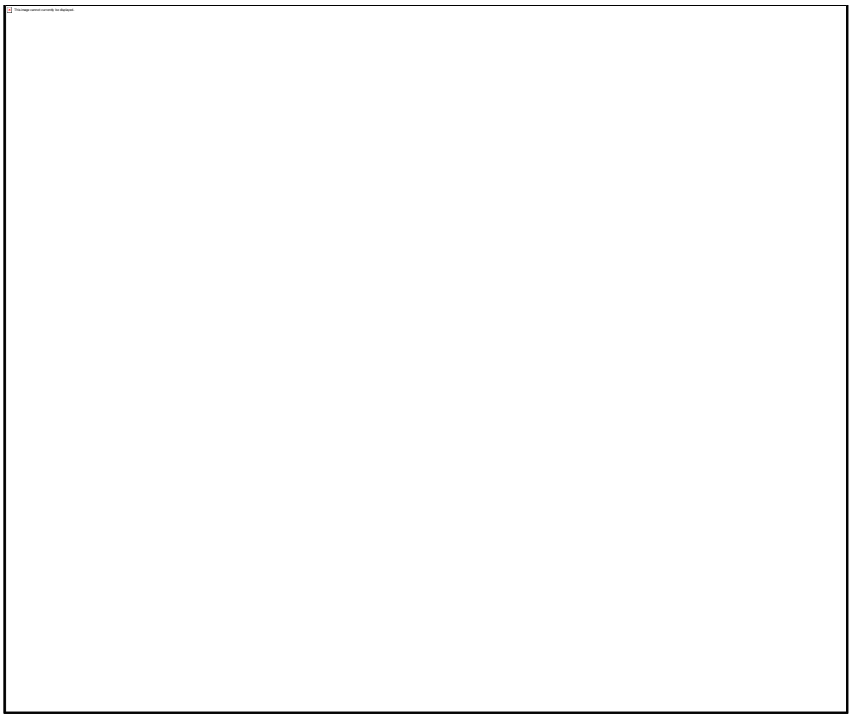

Figure.4. Hydrogel preparation block diagram (solution polymerization/cross-linking procedure)

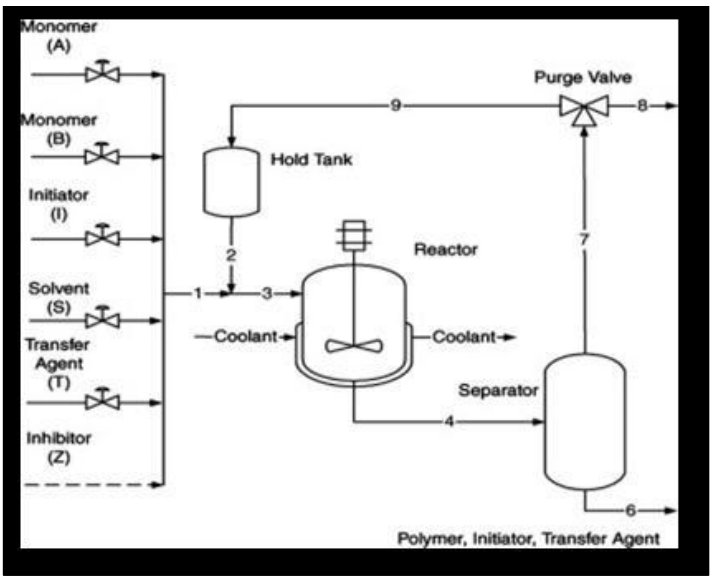

Figure.5. solution polymerization with recycle loop

5. Suspension polymerization

This approach is employed to form spherical microparticles ranging from 1 m to 1 mm in size. The monomer solutions are dispersed in a non-solvent environment to form thin droplets that are

stabilized using a stabilizer. The polymerization procedure is initiated by the thermally decomposed state of the free radical. Unreactive monomers, a cross-linked reagent, and an initiator were rinsed from the produced microparticles. In vitro release studies were conducted to evaluate the readiness of the predefined microspheres. A series of new pH-sensitive co-polymerized microspheres were developed and evaluated by Razzaq R. et al., using modified suspension polymerization of butyl acrylate and itaconic acid, 5% ethylene glycol dimethacrylate, and 1% benzoyl peroxide as initiators. The majority of the microspheres were successfully encapsulated using the equilibrium swelling method, and the percentage yield was approximately 72. Furthermore, a maximum in vitro release study was conducted to evaluate the efficacy of the drug-loaded microspheres.

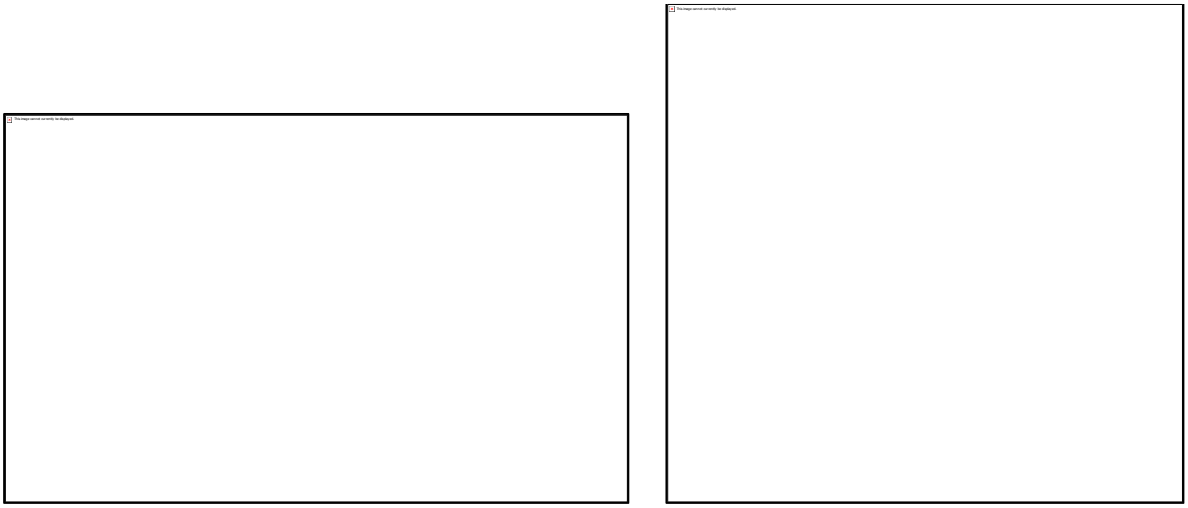

Figure.6. Suspension polymerization with recycle loop

6. Polymerization by irradiation

In this method, high-energy radiation, such as gamma rays or electron beams, is used to create unsaturated molecules. Radicals are created on the polymer chains when the aqueous polymer solution is exposed to radiation. Covalent bonds are formed when the macroradicals are recombined on different chains, creating a cross-link structure. To create the hydrogel, polyvinyl alcohol was crosslinked with 2-acetrylamidinositol (2-AMP) and potassium persulfate was used as the initiator. Captopril was added to the prepared hydrogels and tested in vitro and on animals. The cross-links in the components were confirmed by a FT-IR , XRD , TGA , and DSC analyzes. The hydrogels with captopril had a tmax of 4 hours and a Cmax of 661,853ng/ml.

7. Grafting to support

Bulk polymerized hydrogels have a structurally fragile structure. To improve the mechanical properties of a hydrogel, it can be grafted onto a more robust support surface. In this process, free radicals are generated on a more resilient support surface and monomers are directly polymerized onto the support, resulting in a covalently bonded chain. Various grafting methods have been employed to generate hydrogel materials from a range of polymer supports. One example of this is a starch-grafted hydrogel containing acrylic acid, which was created by the emulsion cross-l-

aminomethyl transfer method with the addition of glutaraldehyde(GA) as cross-linker. This was followed by the addition of acetaminophen(AA) and chitosan(CS) to create IPN (interpenetrating polymer network) microspheres, which were characterized by their spherical shape and smooth surfaces, as demonstrated by SEM and FTIR. These microspheres were further enhanced by encapsulation of up to 74%. The CFX release of the microspheres was extended up to 12 h, and the CFX half-life was also confirmed by FTIR.

PROPERTIES

The use of hydrophilic gels, commonly referred to as hydrogels, has attracted a great deal of attention in the fields of pharmaceutical and biomedical engineering. However, a hydrogel can only be used as a carrier for a drug or other therapeutic biological molecule if it is capable of biodegradability, biocompatibility and nontoxicity in-situ. Therefore, after the biomaterials have been prepared, the characteristic properties such as swelling behavior, mechanical properties and be evaluated for the hydrogel to be successful in the biomedical field in question.

1. Swelling properties

Hydrogels are characterized by their cross-linked polymer chains, either physically or chemically, and are thus considered as a single molecule, regardless of their size. Consequently, no concept of molecular weight is associated with them, and they are sometimes referred to as "infinite large molecules" or "super macromolecules". Rapid and reversible changes in environmental conditions, such as pH, temperature, electrical signal, and the presence of enzymes and other ionic species, can lead to changes in the physical structure of a hydrogel, such as precipitate formation, size, and water content. The volume change is determined by the difference in concentration between the mobile ions in the interior and the external solution, as well as changes in solvent pH. Acetic acid is a pH-sensitive hydrogel, in which the swelling ratio is determined by the degree of ionization of carboxylic groups on the polymer chain.In another study, temperature-dependent phase transitions and the microenvironment of a PNIPAM-based hydrogel were examined in water using 9-4-N-dimethylamino-phenethylamine (DP) as an in-situ intramolecular fluorescent probe. The fluorescence behavior of DP-labeled Gels was affected by the concentrations of monomers and cross-linkers. The thermo metabolic behavior of the PNipam hydrogel was also affected by the co-polymerization of Nipam with the hydrophilic monomers DMAM and MMA, which increased the lower LCST and decreased it in MMA. The results suggest that co-polymer PNipam-DMAM hydrogels with higher LCSTs are more open and water-swollen above their LCSTs, whereas copolymer PGMs with lower LCSTs are less open and water-shrinking below their LCSTs when compared with a PNippam homo- polymer hydrogel.

2. Mechanical properties

The mechanical properties of hydrogels are of paramount importance from a pharmaceutical and biomedical perspective. Assessment of mechanical properties is necessary for a variety of biomedical applications, such as ligament, tendon, wound dressing, drug delivery matrix, tissue engineering, and cartilage replacement materials. It is essential that the mechanical properties of

the hydrogel are such that it can maintain its physical structure during the delivery of therapeutic moieties for a specified period of time. To achieve the desired mechanical properties of a hydrogel, it is possible to alter its degree of crosslinking . Higher crosslinking levels can create a stronger hydrogel, whereas lower crosslinking levels create a more brittle structure. Therefore, there is an optimal degree for crosslinking to obtain a relatively strong yet flexible hydrogel. Copolymerization of a co-monomer may also lead to hydrogen bonding in the hydrogel, which has been used by many researchers to obtain desired mechanical properties.Grassi et al. recently conducted a study to investigate the mechanical properties of hydrogel calcium alginate. The mechanical characterization was based on relaxation experiments (normally stress relaxation at constant deformation) to identify the hydrogel's linear viscosity range and to define the relaxation spectra and the Young's modulus using the generalized Maxwell model. Based on the Young modulus and Flory's theory, the cross- linking density of the hydrogels could be determined, which was then used to calculate the average polymeric mesh size using the equivalent network theory.

3. Biocompatible properties

To be usable in the biomedical field, hydrogels must meet biocompatibility and non-toxic criteria. Most polymers used for this purpose must be tested for cytotoxicity and toxicity in-vivo. Biocompatibility is the capacity of a material to interact with a specific host response in a particular application. It is composed of two components: bio-safety (i.e., an appropriate host response, both systemic and local), and bio-functionality (i.e. ability of the material to perform the specific task it is intended for). This definition is of particular importance in tissue engineering because tissue construction is designed to interact with the body continuously, both during healing and cellular regeneration, as well as during scaffold degradation. Failure to meet this requirement may result in the hydrogel being fouled or in the formation of damaged and scarring tissues, regardless of whether they are immediately adjacent to or connected to the hydrogel via vasculature. Addition, the use of toxic chemicals, such as those used in the polymerization of synthetics, may pose a challenge for biocompatibility in vivo if the conversion is not 100%.It is essential to ensure that all components used in polymerizing and synthesizing hydrogels are safe and reasonably nontoxic. In particular, initiators (organic solvents), stabilizers (monomers), emulsifiers (reacted monomers) and initiators (reactive monomers) used in polymerizations and hydrogels synthesis may be toxic to the host cell if they leak out into the tissue or encapsulated cell. For instance, a commonly used photoinitiator (Irimacell 2959) has been demonstrated to reduce cell viability when used at concentrations greater than 0.1%. To purify gels of hazardous chemicals, it is recommended to follow various purification processes (solvent washing, and dialysis). Gelatin scaffolds, typically with oligomers or pre-mers, present a particular challenge because the reactants used in the synthesis of the gel are injected in the body while the gel is still in the pre-mer solution. Using this technique is beneficial because of its low invasiveness, however, special attention should be paid to ensure the safety of the components used.

Evaluation of biocompatibility

In vitro cell culture protocols are commonly employed to assess the tissue compatibility of implantable medical devices. These cell culture methods are also referred to as cytotoxicity testing. The three main cell culture assays used to assess biocompatibility of hydrogels are: a) extract dilution (b), direct contact (c) agar diffusion (d) and (e). These assays are outlined in the United

States Pharmacopeia and International Standards Organization (ISO). Morphological assays are those in which changes in cell morphology are observed. To assess tissue compatibility for a hydrogel in vivo, it is necessary to understand the biomaterial's chemical composition and the tissue exposure conditions (including the nature, extent, frequency, and duration of the exposure). The principles generally used in the biological assessment of hydrogels include the following:The material or materials used in the production process, intended additives, process contaminants, residues, leachable substances, degraded products, other components, and their interactions with the final product, as well as the characteristics of the finished product, are all important factors in determining the toxicity of a hydrogel. To reduce toxicity, it is recommended to modify the polymerization kinetics and to wash the resultant hydrogel thoroughly. Additionally, the formation of the hydrogel without any initiators and the use of alternative routes such as radiation may address the issue of the remaining initiator. Furthermore, the use of a PVA dehydrogenated hydrogel, which is synthesized by the freeze thaw method, reduces the cytotoxicity caused by the crystals formed. A study was conducted to evaluate the toxicity of PECE in situ formation as a potential ocular sustained drug delivery system. The study also examined the biodegradation of PECE within the eye compartment and the effects of this hydrogel on cultured human lamin epithelium, intraocular pressure, and ocular tissues. The results of this study were generally consistent in terms of biocompatibility and toxicity.

APPLICATIONS

1. In Wound Dressings.

Hydrogel materials are directly exposed to human tissues and are capable of absorbing exudate, resulting in the formation of a gel. As a result, bodily fluids are not lost and adhere to the wound post-absorption. Hydrogels also provide oxygen to wounds, encouraging epithelial cell proliferation and the growth of new capillaries. Furthermore, they protect the wound from bacterial infection, thereby promoting wound healing in general. There is a significant unmet clinical need for hydromagnetic dressings, which are now commercially available. Dressings can be formulated as a spray, emulsion or paste and contain embedded antiseptic drugs that are gradually released into the wound via the gel, thereby accelerating wound healing. A class of peptide based hydrogels has been identified as "smart" hydrogels, which are able to self-assemble ultrashort peptide molecules to form helical fibers. In a rat model of a partial thickness burn, these peptide-structured hydrogels were found to speed up wound closure. Furthermore, the hydrogel could be further enhanced by adding bioactive molecules such as cytokine and growth factors, which could further enhance its regenerative capabilities. Singh et al. have also identified a new type of hydrogel, which is composed of silver nanoparticles and polyvinyl polymer idones, as well as carrageenan. This hydrogel is irradiated to emit gamma radiation, and is capable of providing wound dressings for infection management and skin wound healing in burn and other wounds.

2. In Biosensors

This biosensor is super fast and accurate, and it works in real-time. The biomolecules are either stuck on the surface of the sensor or in the inside of the hydrogel, which connects them to the physical components of the sensors. Usually, the hydrogel is the link between the biomolecule and the physical components. The sensors are made from hydrogels that are usually made with alginate or other acids in a complex,

and the sensor is made of a non enzymatic electrochemical sensor. This sensor was made by in-situ fabrication, and it had a quick amperometric reaction to H2 O2 in 7 seconds. It's a great model for monitoring H2 O2 levels in rat brains, which will help us understand how H2 O2 affects different diseases and processes.. Devadhasan et al. developed a novel approach to measure the pH of various solutions by combining a pH indicator with a hydrogel matrix. This approach enabled a thin film to be fabricated, and the modified gel to display color change across the entire pH range (pH 1-14). The complementary MOS image sensor was then used to absorb the color intensity from the hydrogel, resulting in a high-accuracy analysis based on pH measurement. This method can be used to detect the pH ranges of in-situ applications, such as the detection of toxic chemicals or chemical vapors. The results of this research may be useful for the detection of pH ranges of solutions in the field.

3. In Contact Lenses

Contact lenses are delicate medical instruments used to correct vision or alter eye color for cosmetic purposes, and their ability to absorb and release oxygen is a key factor to consider when designing them. As a result, hydrogels are essential for contact lens manufacturing, as they provide a comfortable wearing experience, good oxygen permeation, and the potential to treat eye diseases. Soft contact lenses are composed of a majority of hydrogels, which are cross-linked with either ethyl benzyl dihydrocrylate or silicon. These hydrogels offer a range of advantages, such as relatively higher water content, improved chemical and thermal stability, and mechanical properties that can be tailored to the wearer's needs, as well as oxygen permeability and drug loading capacity, which are essential for safe day-to-day wear.

CONCLUSION

In recent years, many hydrogel-based networks have been developed and adapted to meet the requirements of different applications. Hydrogels are a type of polymer material that is able to retain a lot of water within their 3D network. They are used in many different industries and locations, so it is important to know what they are used for. Natural hydrogels were eventually replaced by synthetic hydrogels because they absorb more water, last longer, and come from different chemical sources. When exposed to water, these hydrogels have the ability to swell. This review provides an overview of the classification of these hydrogels on different bases, their physical and chemical properties, as well as the technical feasibility of their use, methods, their preparation and applications. From the results of this study, it can be concluded that hydrogels possess outstanding properties that will lead to many future applications as the next generation of biomaterials. There are many different methods to prepare hydrogels. Research has demonstrated the effectiveness of gels, especially hydrogels, in regulating drug concentrations in the body within therapeutic limits over an extended period of time. Because of their high water content and softness, hydrogel-based delivery devices are suitable for oral, ocular, epidermal, and subcutaneous applications. This is why hydrogels are also called smart biomaterials.

REFERENCES

1. Nguyen QuangVinh, Dai Phu Huynh, Jae Hyung Park, Doo Sung Lee (2015) Injectable polymeric hydrogels for the delivery of therapeutic agents: A review. European Polymer J 72: 602-619.
2. Janani Radhakrishnan, Uma Maheswari Krishnan, Swaminathan Sethuraman (2014) Hydrogel based injectable scaffolds for cardiac tissue regeneration. Biotech Adv (32)2: 449-461.
3. Thambi Thavasyappan, Doo Sung Lee (2017) Injectable hydrogels for sustained release of therapeutic agents. J Controlled Release 267: 57-66.
4. Hoffman Allan S (2012) Hydrogels for biomedical applications. Adv Drug Del Rev 64:18-23.
5. FaheemAkhtar Muhammad, Muhammad Hanif, Nazar Muhammad Ranjha (2016) Methods of synthesis of hydrogels A review. Saudi Pharm J 24, 554-559.
6. Ansuja Pulickal Mathew, Saji Uthaman , Ki Hyun Cho, Chong Su Cho, In Kyu Park (2018) Injectable hydrogels for delivering biotherapeutic molecules. Inter J Bio Macromolecules 110: 17-29.
7. Michael S Riederer, Brennan D Requist, Karin A Payne, J Douglas Way, Melissa D Krebs (2016) Injectable and microporous scaffold of densely packed, growth factor encapsulating chitosan microgels. Carbohydrate Polymers 152: 792-801.
8. Settimio Pacelli, Francisca Acosta, Aparna R Chakravarti , Saheli G Samanta , Jonathan Whitlow, et al. (2017) Nanodiamond based injectable hydrogel for sustained growth factor release: Preparation, characterization and in vitro analysis. Acta Biomaterialia 58: 479-491.
9. Jeanie L Drury, David J (2003) Mooney Hydrogels for tissue engineering: scaffold design variables and applications. Biomaterials, 24: 4337 4351.
10. Ying Luo, James B Kobler, James T Heaton, Xinqiao Jia, Steven M Zeitels (2010) Injectable Hyaluronic Acid Dextran Hydrogels and Effects of Implantation in Ferret Vocal Fold. Wiley Inter Science 93(2): 386-393.
11. Masoud Ghorbani, Jafar Ai, Mohammad Reza Nourani , Mahmoud Azami , Batool Hashemi Beni (2017) Injectable natural polymer compound for tissue engineering of intervertebral disc: In vitro study. Mater Sci Engineering 80: 502-508.
12. Amit Alexander , Ajazuddin , Junaid Khan , Swarnlata Saraf , Shailendra Saraf (2014) 5 Polyethylene glycol (PEG)–Poly(N isopropylacrylamide) (PNIPAAm) based thermosensitive injectable hydrogels for biomedical applications. Eur J Pharm Biopharm 88: 575-585.
13. James D Kretlow , Leda Klouda, Antonios G Mikos (2007) Injectable matrices and scaffolds for drug delivery in tissue engineering. Adv Drug Deliv Rev 59, 263-273.
14. Singh A, Sharma PK, Garg VK, Garg G. Hydrogels: a review. Int. J. Pharm. Sci. Rev. Res. 2010;4(2):97-105.
15. Mohite PB, Adhav SS. A hydrogels: Method of Preparation and applications. Int. J. Adv. Pharma. 2017; 6(3):79-85.
16. Zaman M, Siddique W, Waheed S, Muhammad SS, Mahmood A, Qureshi J et al. International Journal of Biology, Pharmacy and Allied Sciences. 2015; 4(12):6581-6603.
17. Rana P, Ganarajan G, Kothiyal P. Review on Preparation and Properties Hydrogel Formulation, World Journal of Pharmacy and Pharmaceutical Sciences. 2015; 4(12):1069-1080.
18. Yang L, Chu JS, Fix JA. Colon-specific drug delivery: new approaches and in vitro/in vivo evaluation. International Journal of Pharmacy. 2002; 235:1-15.
19. Tan H, Marra KG. Injectable, biodegradable hydrogels for tissue engineering applications. Materials. 2010; 3:1746-1767.

20. Susana S, Figueiras A, Veiga F. Modular Hydrogels for Drug Delivery, Journal of Biomaterials and Nanobiotechnology. 2012; 3:185-199
21. Jong SD, Eerdenbrugh V, Van B, Nostrum CV, Bosch KJ, Hennink W. Physically cross linked dextran hydrogels by stereo complex formation of lactic acid oligomers: degradation and protein release behavior. Journal of Controlled Release. 2001; 71:261-275.
22. Das N. Preparation methods and properties of hydrogel: A review, Int. J. Pharm. Pharm. Sci, 2013; 5(3): 112–17.
23. Enas MA. Hydrogel: Preparation, characterization, and applications: A review. J. Adv. Res. 2015; 6:105-21
24. El-Sherbiny IM, Yacoub MH. Hydrogel scaffolds for tissue engineering: Progress and challenges. Glob. Cardiol. Sci. Pract. 2013; 2013(3): 316–42.
25. Thakur VK, Thakur MK, Kessler MR. Handbook of Composites from Renewable Materials, PolyComp. 2017; 6(7); 1-638
26. Dwivedi S, Khatri P, Mehra GR, Kumar V. Hydrogel- A conceptual overview. Int. J. Pharm. Biol Arch. 2011; 2(6): 1588-97.
27. Siddeswara M, Purushothaman M, Kumar MP, Raja MS, Yasmin S, Swathi R. Formulation and Evaluation of Desvenlafoxacine Succinate Hydrogel. Int.J. Curr. trends Pharm. Res. 2016; 4(5); 42-60
28. Chen J,Li D,Koshikawa H, Asano M, Maekawa Y, ―Crosslinking and grafting of polyetheretherketone film by radiation techniques for application in fuel cells,J. Membrane Sci - J Membrane SCI, 2010; 362(2): 488–94.
29. Iwai K, Hanasaki K, Yamamoto M. Fluorescence label studies of thermo-responsive poly(N-isopropylacrylamide) hydrogels. J Luminescence 2000; 1289: 87-89.
30. Grassi M, Sandolo C, Perin D, Coviello T, Lapasin R, Grassi G. Structural characterization of calcium alginate matrices by means of mechanical and release tests. Molecules 2009; 14: 3003-3017.
31. Bryant SJ, Nuttelman CR, Anseth KS. Cytocompatibility of UV and visible light photoinitiating systems on cultured NIH/3T3 fibroblasts in vitro. J Biomater Sci Polym Ed. 2000; 11: 439-457.
32. Yin H, Gong C, Shi S, Liu X, Wei Y, Qian Z. Toxicity evaluation of biodegradable and thermosensitive PEG-PCL-PEG hydrogel as a potential in situ sustained ophthalmic drug delivery system. J Biomed Mater Res B. 2010; 92: 129-137.