IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
IJARSCT
Impact Factor: 6.252
Volume 2, Issue 7, May 2022

Methods for Synthesis and Applications for Synthetic Hydrogel – A Review

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Abstract: *Hydrogels are polymeric networks possessing the ability to uptake a large amount of water in their gel structure. Hydrogel consists of up to 90 % of water absorption capacity due to this hydrogel have lot of applications in coal dewatering, food additives, pharmaceuticals, biomedical, diaper, agricultural, wound dressing and medical field. With the help of hydrogel, we can easily deliver of various drugs, medicines from one place to another place. Due to their higher water absorption capacity, long service life hydrogel has lot of applications. Hydrogels have ability to sense changes of pH, temp. and concentration of metabolite. Hydrogels also possess good transport properties and easy to modification. Hydrogels also possess good transport properties and easy to modify and have highest durability and stability. Environmentally sensitive hydrogels have the ability to sense changes of pH, temperature or the concentration of metabolite and release their load as result of such a change. Due to high-water content, porosity and soft consistency hydrogel closely simulate natural living tissue than any other class of synthetic biomaterials. Skin is largest organ of human body and drug delivery through route called transdermal drug delivery system.*

Keywords: Electrosensitive Hydrogel Synthesis, Acrylamide and Acrylic acid, Swelling ratio, AAm/AAc Monomer Ratio

I. Introduction

Hydrogel products constitute a group of polymeric materials hydrophilic structure of which renders them capable of holding large amounts of water in three-dimensional networks. These products have number of industrial and environmental areas of application considered to be of prime importance. Natural hydrogels gradually replaced by synthetic types due to their higher water absorption capacity, long service life and wide varieties of raw chemical resources. Hydrogels to absorb water arises from hydrophilic functional groups attached to polymeric backbone and their resistance to dissolution arises from cross-links between network chains. Hydrogels have defined as two- or multicomponent systems consisting of a three-dimensional network of polymer chains and water that fills the space between macromolecules. Natural Hydrogels were gradually replaced by synthetic hydrogels which has long service life, high capacity of water absorption and high gel strength. Hydrogel-forming natural polymers include proteins such as collagen and polysaccharides such as starch, alginate. Hydrogels traditionally prepared by chemical polymerization methods. Hydrogels three- dimensional, hydrophilic, polymeric networks capable of absorbing large amounts of water or biological fluids.

II. LITERATURE REVIEWS

Acrylic acid (AA) and sodium or potassium salts and acrylamide (AM) frequently use in hydrogel industrial production. Two pathways to prepare acrylic hydrogel polymerization and cross-linking by polyvinyl cross-linker and crosslinking of water- soluble prepolymer by polyfunctional cross-linker. Polymerization of acrylic acid (AA) and its salts with cross-linker used for hydrogel preparation. Carboxylic acid groups of product neutralized before or after polymerization. Initiation is most often carried out chemically with free-radical azo or peroxide thermal dissociative species or by reaction of a reducing agent with an oxidizing agent. [1].

Experimental analysis polymer with monomer ratio of acrylamide to acrylic acid 70:30 taken and immersed in 500 mL solutions of pH ranging from 3.75 to 9.6. At lower pH, carboxylic acid in copolymer structure turns into protonated form of carboxylic acid. Hydrogel in acidic environment gets less water to absorb and hence swelling ratio decreases at lower pH.

At higher pH carboxylic acid group gets transformed into its basic salt form. [4].

Copolymer with monomer ratio 70/30 of acrylamide and acrylic acid synthesized by maintaining reaction temperatures of 50 °C, 60 °C and 70 °C. Preparing 70/30 monomer ratio, amount of MBA increased to 0.06, 0.07 and 0.08 gm and swelling ratios 300, 200 and 100. A 70/30 polymer put in different concentrations of salt solution from 0.1 to 0.9 gm of NaCl salts strength of solution initially decrease and finally increase. [4]

Hydrogels were prepared by Pourjavdi et al. using direct grafting of acrylamide (AAm) monomer onto chitosan using ammonium persulfate (APS) as an initiator and methylene bis acrylamide (MBA) as a crosslinking agent under an inert atmosphere. The effect of AAm and MBA concentrations on swelling capacity of hydrogel. Polymer structures characterized by FTIR spectroscopy. Water absorbencies of hydrogels compared before and after alkaline hydrolysis treatment. [5].

Saponification of acrylamide (PAAm) with hot sodium hydroxide solution rise to high water absorbency. Swelling of hydrogel samples in saline solutions. Swelling capacity of chitosan-g PAAm hydrogels in $CaCl_2$ and $AlCl_3$ solutions higher than hydrolyzed chitosan-PAAm hydrogels. Chitosan-g- PAAm and H-chitosan-g-PAAm hydrogels different swelling capacities in various pH. [5].

Polyacrylic acid (PAA) homopolymeric hydrogel and Its commercial version contains 2.5 % of PAA and 97.5 % of water. It is stable and optimal elasticity property. When used as an endoprosthesis it designed to be non-toxic, non-inflammatory and to imitate surrounding soft tissue. Polyethylene glycol diacrylate (PEGDA) hydrogels modified with β-chitosan, which has improved biocompatibility. The hydrogel is formulated by adding 10 % aqueous solution of PEGDA into 2% solution of chitosan in acetic acid. The mixture is cross-linked by UV radiation to form the hydrogel. This hydrogel displays IPN structure and contains 77-83 % of water. [7]

III. APPLICATIONS OF HYDROGEL PRODUCTS

1. Hydrogel applied to Hygienic Products.
2. Agriculture Industries.
3. Drug delivery systems.
4. Sealing.
5. Coal Dewatering.
6. Artificial Snow
7. Food Additives
8. Pharmaceuticals.
9. Biomedical applications.
10. Tissue Engineering.
11. Diagnostics.
12. Wound dressing.
13. Separation of Biomolecules or Cells.
14. Barrier Materials Regulate Adhesions.
15. Biosensor.
16. Regenerative Medicines.
17. Diaper Industries.
18. Good oxygen Permeability.
19. Soft Contact Lenses.
20. Aqueous Surface Environment to Protect Cells.
21. Industrial Applicability.
22. Rectal Delivery.
23. Perfume Delivery.

Technical Features of Hydrogel

1. The highest absorption capacity in saline.
2. Desired rate of absorption.
3. The highest absorbency under load (AUL).
4. Lowest soluble content and residual monomer.
5. The lowest price.
6. The highest durability and stability in the swelling environment and during the storage.
7. The highest biodegradability without formation of toxic species
8. pH-neutrality after swelling in water.
9. Colorlessness, odor lessness and non-toxic.
10. Photo stability.
11. Re-wetting capability
12. Show lowest soluble content and monomer.

Advantages of Hydrogels

1. Due to their significant water content they possess a degree of flexibility.
2. Release of medicines or nutrients timely.
3. Biocompatible, biodegradable and injected.
4. Hydrogels have ability to sense changes of pH, temp. and concentration of metabolite
5. Hydrogels also possess good transport properties and easy to modification.
6. Hydrogels Improved drug utilization.
7. Decreased side-effects.
8. Flexibility similar to natural tissues.
9. Improved patient compliance.
10. Sustained and prolonged action.

Disadvantages of Hydrogels

1. High cost.
2. Can be hard to handle.
3. Low mechanical strength.
4. Non-adherent and secured by secondary dressing.
5. Difficult to load with drugs/nutrients

Advantages of Hydrogel Polymer in Agriculture

1. Improve growth and crop productivity of Navel orange sandy soil conditions.
2. Increasing seedling survive ratio, enhancing root growth under stress conditions.
3. Increase water-use efficiency and provide a regular supply of water and nutrients.
4. Increase the soil’s ability to reserve irrigation water for as long as possible.
5. Reduce soil erosion and reduces desertification of agricultural lands.
6. Improve nutrients efficiency and provide water.
7. Improve the nutritional status of the plant.
8. Reduce the fertilizers loss by leaching.
9. Protect environmental by reducing soil and water pollution.

Effect of Hydrogel Polymer on Soil Polymers

1. Increasing the soil holding capacity.
2. Increasing the efficiency of irrigation water use.
3. Reducing the quantities of irrigation water which reducing irrigation costs.

4. Increase field capacity of light soils for long time.
5. Improving the permeability of heavy soils as a result of reducing the fusion of granules
6. Reduce soil erosion.

Technologies Adopted in Hydrogel Preparation

Hydrogels are polymer networks having hydrophilic properties. While hydrogels are generally prepared based on hydrophilic monomers, hydrophobic monomers are sometimes used in hydrogel preparation to regulate the properties for specific applications. 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. Hydrogel is a hydrophilic polymeric network cross-linked in some fashion to produce elastic structure. Copolymerization/cross-linking free-radical polymerizations are commonly used to produce hydrogels by reacting hydrophilic monomers with multifunctional cross-linkers. Polymerization techniques can be used to form gels, including bulk, solution and suspension polymerization. To control heat of polymerization and final hydrogels properties, diluents can used. Hydrogel needs to washed to remove impurities left from preparation process. Preparation of hydrogel based on acrylamide, acrylic acid and its salts by inverse-suspension polymerization.

Hydrogels usually prepared from polar monomers. Natural polymer hydrogels, synthetic polymer hydrogels and combinations of the two classes. From a preparative point of view can obtained by graft polymerization, cross-linking polymerization, networks formation of water-soluble polymer and radiation cross-linking etc. Lightly cross-linked copolymers of acrylate and acrylic acid and grafted starch-acrylic acid polymers prepared by inverse suspension, emulsion polymerization, and solution polymerization. Water-soluble linear polymers of both natural and synthetic origin are cross-linked to form hydrogels in a number of ways.

1. Linking polymer chains via chemical reaction.
2. Using ionizing radiation to generate main-chain
3. Physical interactions such as entanglements, electrostatics, and crystallite formation.

Chemicals and Raw Materials for Hydrogel Synthesis

1. Acrylamide (AAm)
2. Tetramethylene Ethylene Diamine (TEMED)
3. Potassium Peroxodisulfate (KPS)/Ammonium Persulphate (APS)
4. Methylene Bis Acrylamide (MBA)
5. Methanol
6. Acrylic acid (AAc)
7. Distilled Water.
8. 0.1N HCL and 0.1 N NaOH for maintain pH.

Important Properties of hydrogel Swelling Ratio

Swelling is the important factor for hydrogel which express the capacity of amount of water that can retain by hydrogel (or absorbed). To know the water absorption capacity of the hydrogel a sample of the prepared hydrogel (0.5 gm) was put in 100 mL distilled water for 16 -18 hours and the initial weight of the hydrogel is compared with the final weight. The degree of swelling is found by the swelling ratio. The swelling ratio increases with increase in pH. This is because the number of fixed charges on the gel increases as more carboxylic groups get converted to their basic salt form. This increases electrostatic repulsion between polymer chains and allows more water to get absorbed.

$$\text{Swelling Ratio} = [W_s - W_d] / W_d$$

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

Ionic Strength

Ionic strength is the strength of cross linking of the two polymer and it depends on the ratio of polymer which used time of synthesis of hydrogel. The optimum ratio of polymer is important for ionic strength. As decrease in concentration of cross linker leads to increased swelling in the polymer but that time strength decrease. the effect of pH and ionic strength shows that hydrogels respond to change in environment during swelling. With increase in ionic strength and the swelling decreases as electrostatic attraction increases between chains.

Porosity

Porosity is a morphological feature of a material that can be simply described as the presence of void cavity inside the bulk. It is useful to control the porosity in many devices for a wide variety of applications such as optimal cell migration in hydrogel-based scaffolds or tunable lode/release of macromolecules.

III. CONCLUSION

We study the various applications, methods of preparation of hydrogel and materials to be use for hydrogel synthesis. As per literature, effect of pH and ionic strength shows that hydrogels respond to change in environment during swelling. The swelling ratio increases with increase in pH and with increase in ionic strength and the swelling decreases as electrostatic attraction increases between the chains. While preparation of polymer changing reaction, conditions leads to different swelling in samples. The pH of distilled water modified either by adding HCl to decrease pH or NaOH to increase the pH. Decrease in concentration of cross linker leads to increased swelling in the polymer but its strength decreases. Hydrogels prepared according to various proportions of the monomers, acrylamide and acrylic acid have different swelling properties. The swelling ratios of various batches largely depends on the ratio of monomers taken in the reaction mixture. As the pH of the solution increases the amount of swelling increases. This is because the number of fixed charges on the gel increases as more carboxylic groups get converted to their basic salt form. This increases electrostatic repulsion between the polymer chains and allows more water to get absorbed. With increase in concentration of the crosslinker MBA the swelling decreases since the density of cross-linking increases and available spaces for water absorption become lesser. The ionic strength of the solution in which hydrogel is immersed also has an impact on absorption capacity. The electrostatic repulsion between crosslinked chains decreases with increasing NaCl concentration as it tends to partially neutralize the carboxylic acid attached to polymer chains. Lesser amount of water is absorbed at high strength.

REFERENCES

[1]. Ahmed Enas, Hydrogel: Preparation, characterization, and applications: A review,
[2]. Department of Chemical Engineering & Pilot Plant, National Research Centre, Doka, Giza, Egypt, Production and hosting by Elsevier B.V. on behalf of Cairo University, Journal of Advanced Research, 2015, 105-121.
[3]. 2. Dr. Ajeet Godbole, Dr. Shilpa Bhilegaokar, Pankaj Gadara and Shivani P Hydrogels Introduction, Preparation, Characterization and Applications Department of Pharmaceutics, Ponda Education Society's Rajaram and Tarabai Bandekar College of Pharmacy, Farmagudi, Ponda, Goa, India, International Journal of Research Methodology, Ijrm, Human, 2015; Vol. 1 (1): 47- 71.
[4]. Divya Juyal, Shailesh Kumar Singh and Archana Dhyani Hydrogel: Preparation, Characterization and Applications, Director, Assistant Professor and Research Scholar Himalayan Institute of Pharmacy & Research, Rajawala, Dehradun, Uttarakhand, India, The Pharma Innovation Journal 2017; 6(6): 25-32, ISSN (E): 2277- 7695 ISSN (P): 2349-8242.
[5]. Dhruv Patel, Nishi Panchal, Nimish Shah Synthesis of Hydrogels Chemical Engineering Department, Institute of Technology, Nirma University, Ahmedabad, Gujarat, India, 4 the International Conference on Multidisciplinary Research & Practice (4ICMRP-2017), ISBN: 978- 93-5288-448-3.
[6]. Deghiedy Noha Mohamed, Synthesis and Characterization of Superabsorbent Hydrogels Based on Natural Polymers Using Ionizing Radiations, Al-Azhar University (Girls) Faculty of Science Chemistry Department, Thesis Submitted
[7]. to Faculty of Science Al-Azhar University (Girls) Cairo in the partial fulfilment for M.Sc. Degree in Chemistry (Organic Chemistry) National Centre for Radiation Research and Technology, Atomic Energy Authority 2010.
[8]. Haesun Park, Jun Chen and Kinam Park, Synthesis of super porous hydrogels: Hydrogels with fast swelling and superabsorbent properties Purdue University, School of Pharmacy, West Lafayette, Indiana 47907-1336 Received 11 February 1998; accepted 13 July 1998, Chen, Park, and Park, 1999 John Wiley & Sons, Inc.

[9]. Nilimanka Das, Preparation Methods and Properties of Hydrogel: A Review Regional Institute of Pharmaceutical Science & Technology, Abhoynagar, Agartala 799 005, Tripura, India, International Journal of Pharmacy and Pharmaceutical Sciences ISSN- 0975-1491 Vol 5, Issue 3, 2013.

[10]. Popat B. Mohite and Sonali S. Adhav, A hydrogels, Methods of preparation and applications, Department of Quality Assurance Techniques and PG studies, College of Pharmacy, Sonai. Affiliated to Savitribai Phule Pune University, Tal. Newasa, Dist. Ahmednagar, State. Maharashtra, India 414105, International Journal of Advances in Pharmaceutics 2017; 06(03): 79-85, ISSN: 2320-4931.

[11]. Somasundar Mantha , Sangeeth Pillai and Parisa Khayambash, A Review Smart Hydrogels in Tissue Engineering and Regenerative Medicine, McGill Craniofacial Tissue Engineering and Stem Cells Laboratory, Faculty of Dentistry, McGill University, 3640 University Street, Montreal, QC H3A 0C7, Canada, Materials 2019, 12, 3323.

[12]. Soumia Chirani, History and Applications of Hydrogels, Physique et macromeléculaire, Department de pharmacies, Faculty de medicine, University Djalili Liabés, Sidi Bel-Abbès, Algeria, Journal of Biomedical Sciences ISSN 2254-609X, Vol. 4 No. 2:13,2015.

[13]. Waleed Fouad Abobatta, Hydrogel Polymer: A New Tool for Improving Agricultural Production Citrus Department, Horticulture Research Institute, Agriculture Research Centre, Egypt, Academic Journal of Polymer Sci 3(2): AJOP.MS.ID.555608 (2019), ISSN,2641-8282.

NOMENCLATURE

AAc - Acrylic Acid AAm - Acrylamide
APS - Ammonium Persulfate
HLB - Hydrophilic–Lipophilic-Balance KPS - Potassium Peroxydisulfate
MBA - Methylenebisacrylamide PAA - Polyacrylic Acid
PAN - Polyacrylonitrile
PEGDA - Polyethylene Glycol Diacrylate PEI - Polyethyleneimine
TEMED - Tetramethylene Ethylene Diamine