



HYDROGELS AND THEIR APPLICATION AREAS

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Abstract: *Hydrogels, being polymeric material, are named “Hydrophilic Polymer” because of their capable of holding large amounts of water in their three-dimensional networks. Hydrogels is not solved in water; however they have been swollen to their balance volume. Because of this swell behavior, they can adsorb big quantity of water in this structure. So they can term of “three sized polymers” due to protect their existing shape. Their cross linked bound structures are able to covalent or ionic and also one polymer which can for use of hydrogel polymer, must have hydrophilic groups such as carboxyl, carbonyl, amine and amide in main chains or side chains, and because of these groups water bound the polymer and polymer start to swell with rising volume and mass. Swell behavior of hydrogel is interested in quantity of hydrophilic groups. Hydrogels can use in different industrial and environmental areas with this high amount water holding capacity. They are used in food industry, biomedical, bioengineering, biotechnology, veterinary, pharmacist, agriculture, telecommunication, etc. Especially in current life, baby nappy has been including inside hydrogel beads. Also they used in contact lens, artificial cornea, synthetic cartilage and gullet, controlled medicine release, surgery yarns. This article general inform about usage area of hydrogels.*

Key words: *Hydrogels, Leather, Hydrophilic Polymers, three-dimensional networks*

1. INTRODUCTION

Polymers are known that compounds of high molecular weight or macromolecules, which is a very large, chain-like molecule made up of monomers. They are derived by the condensation of monomers or polymerization reaction. Polymers can be classified two types according to monomer structure. If polymer consist of same monomers, polymer term of homopolymer or if the polymer is consist of different monomers, they are qualified as copolymer. Polymer according to polymerization reaction can be linear, branched or cross-linked [1]. Cross-linked polymers can not be solved any solvent and if the polymer keep waiting in any solvent, polymer start to swell because of three-sized networks and being covalent bounding. These types of polymers are named in xerogels. Xerogels which has got the swelling ability, take inside the solvent more than % 20 of gel mass [2]. If the solvent is water, this cross-linked structure is named hydrogel. A hydrogel is a network of polymer chains that are hydrophilic, sometimes found as a colloidal gel in which water is the dispersion medium. Hydrogels are highly absorbent (they can contain over 90% water) natural or synthetic polymeric networks [3], [4]. Hydrogels term first was in scientific literature as colloidal gel of inorganic salts in 1894 [5]. However poly (2-hydroxyethyl methacrylate) p (HEMA) hydrogel which has got the cross-linked macromolecular network structure and can swell in the water, is today use as contact lens, was found by Wichterle and Lim in 1954 [6]. In 1958 poly vinyl acrylate p

(PVA) hydrogel was produced by Gamma radiation and cross-linked poly (ethylene glycol) (PEG) was produced in 1970 by Gamma radiation [7], [8]. Pluronic hydrogels which product for drug release, used for the first time in 1972 [9]. Polyethylene glycol–polylactic acid (PEG–PLA) hydrogel was produced in 1993 by photo polymerization method and thermal characterization of same hydrogel was researched in 1997 [10]. Hybrid hydrogel combination of synthetic and natural polymers was searched in 1993 [11], [12]. First commercial gel which is named “Smart Gel”, which was launched to market in 1996, was soft and flexible and also was hardened in body temperature [13]. This smart gel has been especially used for foot comfort and support inside footwear (Fig. 1:).



Fig.1: a) Contact Lens [29] b) Smart Gel [30]

2. GENERAL INFORMATION

2.1 Water Position in Hydrogels and Swell Behaviour

A polymer which has got the polar and hydrophilic function groups as $-OH$, $-NH_2$, $-COOH$, $-COOR$, describe a hydrogel. These groups are interacted with the water by the hydrogen bonding [14]. Volume and mass of hydrogel polymer increase with this bounding water in hydrogel and gel start to swell. Also quantities of hydrophilic groups have raised the swell effect. Swell is characteristic feature of polymeric network structure and it is sudden change of volume in polymer. According to cross linked quantity, polymeric network can adsorb high quantity liquid without solved. Swell feature of a polymeric gel is determined interaction of functional groups with each other and with diluent [15] Push and pull effect between chains, electrostatic interactions that are not covalent, Van der Waals; are not influenced from hydrogen bonding. Hydrophobic interactions are this type of physical cross linked interactions and this situation is affected of swell behavior [16] (Fig. 2).

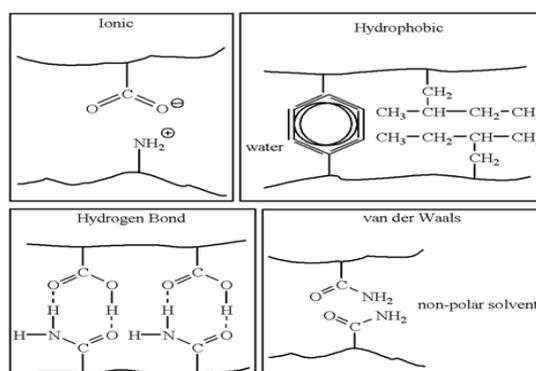


Fig. 2: Molecular Interactions in Hydrogels [15]

In figure 3 show a swelled hydrogel and hydrogel is found three type of water molecule. Bounding water molecule is attached to polar groups of polymer by hydrogen bonding. Free water molecule fill in the pore of the polymer. It behaves like normal water and it does not interact with the polymer. Interface water molecule swarm around the hydrophobic groups of polymer and Bounding of this molecule is not powerful interaction [15]

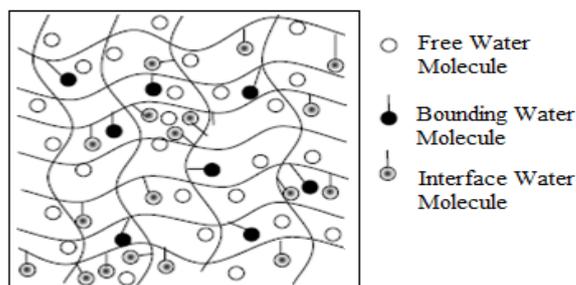


Fig. 3: Schematic View of Swelled Hydrogel [15]

2.2 Types of Hydrogels

2.2.1 Homopolymer Hydrogels

Homopolymer hydrogels occur from one type of monomers. These types of hydrogels are used for important application area like contact lens or drug release. poly (2-hydroxyethyl methacrylate) p(HEMA), poly (1-glycerol methacrylate), poly(hydroxypropyl methacrylate) can give sample for common usage homopolymer hydrogels [17], [18].

2.2.2 Copolymer Hydrogels

Copolymer hydrogels have been prepared by cross linked of two comonomers. However at least one monomer has to be hydrophilic structure. Cross-linked of copolymer hydrogels occur by covalent or ionic interactions. poly(HEMA-co-acrylic acid) p(HEMA-ko-AA) and poly(2-hydroxyethyl methacrylate-co-methyl methacrylate) poly (HEMA-co-MMA) are most common used copolymer hydrogels [19],[20].

2.2.3 Non Ionic Hydrogels

Ionic hydrogels are homopolymeric and copolymeric neuter hydrogels without including load groups. Swell and shrinkage properties of these hydrogels generally occur that a result of changing of environmental temperature [21]

2.2.4 Ionic Hydrogels

Ionic hydrogels, also known polyelectrolytes, is prepared from ionic monomers. This type of hydrogels can be cationic or anionic hydrogels according to positive or negative monomers. Also ionic hydrogel is term of polyampholytic hydrogels, if hydrogel polymer keeps together both anions and cations. Loading groups, being located in main chain of ionic hydrogels, increase susceptibility to warning. These ionic network structures include both acidic and basic groups. These groups ionized in suitable pH and ionic conditions and constant loads are occurred in hydrogel. Because of electrostatic repulse power of these ions, much more dilute can go inside network structure and in this way swell effect degree increase [22], [23].

2.3 Hydrogel Synthesis

2.3.1 Bulk Polymerization

Bulk hydrogels can be formed with one or more types of monomers. Usually, a small amount of cross-linking agent is added in any hydrogel formulation. The polymerization reaction is normally initiated with radiation, ultraviolet, or chemical catalysts. The choice of a suitable initiator depends upon the type of monomers and solvents being used. The wide variety monomer can use in order to obtain desired hydrogel for a given application. The polymerized hydrogel may be produced in a wide variety of forms including films and membranes, rods, particles, and emulsions [24].

2.3.2 Solution Copolymerization with Cross-linking

In this reaction, can use mixing of ionic or neutral monomers with the multifunctional crosslinking agent. The polymerization is initiated thermally by UV-irradiation or by a redox initiator system. The prepared hydrogels need to be washed with distilled water to remove the monomers. Typical solvents used for solution polymerization of hydrogels include water, ethanol, water–ethanol mixtures, and benzyl alcohol. The synthesis solvent may then be removed after formation of the gel by swelling the hydrogels in water [3].

2.3.3 Suspension Polymerization

Dispersion polymerization is used in order to obtain microspheres (beads). In this technique, the monomers and initiator are dispersed in the hydrocarbon phase as a homogenous mixture. The viscosity of the monomer solution, agitation speed, rotor design, and dispersant type mainly governs the resin particle size and shape [25],[26].

2.3.4 Polymerization by Irradiation

Ionizing high energy radiation, like gamma rays and electron beams, has been used as an initiator to prepare the hydrogels of unsaturated compounds. Examples of polymers crosslinked by the radiation method are poly (vinyl alcohol), poly(ethylene glycol), and poly(acrylic acid). The major advantage of the radiation initiation over the chemical initiation is the production of relatively pure and initiator-free hydrogels [18]

2.4 Usage Areas of Hydrogels

Hydrogels have got lots of application areas because of high capacity swelling property in water solution [8]. They are used in food industry, biomedical, bioengineering, biotechnology, veterinary, pharmacist, agriculture, telecommunication, etc. Especially in current life, baby nappy has been including inside hydrogel beads [27], [28]. Also they used in contact lens, artificial cornea, synthetic cartilage and gullet, controlled medicine release, surgery yarns (Fig. 4 ve Fig. 5).



Fig. 4: Hydrojel Beads [31], [32]



5. CONCLUSIONS

Nowadays, hydrogels are used more different application areas such as industry, environmental, medicine, healthy, etc because of the high capacity water uptake. Especially this important property is chosen in order to remove dye or heavy metal adsorption from waste waters. In this purpose loss of polymers and their combinations are utilised, and adsorption labours have made real according to target material which is wanted to adsorb.

REFERENCES

- [1] R. S. Wayne, S. Wilfred, T. W. Campbell, "Preparative methods of polymer chemistry", Wiley-Interscience, 2001, pp. 488.
- [2] W.R. Sorenson, W. F. Sweeny and T.W. Campbell, "Preparative Methods of Polymer Chemistry", John Wiley & Sons Inc., Us, 2001.
- [3] E.M. Ahmed, "Hydrogel: Preparation, characterization, and applications: A review", JARE, Vol. 6(2), pp. 105–121, 2015.
- [4] Y. Osada, Y. and A.R. Khoklov, "Polymer Gels and Networks", Marcel, Dekker Inc., New York, 2001.
- [5] K.H. Syed, I. Gulrez and A. Saphwan, "Hydrogels: Methods of Preparation, Characterisation and Applications", pp1-35, Available: <http://www.intechopen.com/books/progress-in-molecular-and-environmental-bioengineering-from-analysis-and-modeling-to-technology-applications/hydrogels-methods-of-preparation-characterisation-and-applications>.
- [6] J.M. Van Bemmelen, "Der Hydrogel und das kristallinische Hydrat des Kupferoxydes", Z. Anorg. Chem. Vol. 5, p.466, 1894.
- [7] A. Danno, "Gel formation of aqueous solution of polyvinyl alcohol irradiated by gamma rays from cobalt-60", J. Phys. Soc. Jpn. Vol. 13, 1958, pp. 722–727, 1958.
- [8] O. Wichterle and D. Lím, "Hydrophilic gels for biological use", Nature, 185, pp. 117–118, 1960.
- [9] P.A. King, P.A. and J.A. Ward, "Radiation chemistry of aqueous poly(ethylene oxide) solutions". I, J. Polym. Sci. A Polym. Chem, vol. 8, pp. 253–262, 1970.
- [10] R.M. Nalbandian, R.L. Henry, H.S. Wilks, "Artificial skin. II. Pluronic F-127 Silver nitrate or silver lactate gel in the treatment of thermal burns", J. Biomed. Mater. Res, vol. 6, pp.583–590, 1972.
- [11] A.S. Sawhney, C.P. Pathak, J.A. Hubbell, "Bioerodible hydrogels based on photopolymerized poly (ethylene glycol)-co-poly (α -hydroxy acid) diacrylate macromers", Macromolecules, vol. 26 ,pp.581–587, 1993.
- [12] B. Jeong, Y.H. Bae, D.S. Lee, S.W. Kim, "Biodegradable block copolymers as injectable drug-delivery systems", Nature, vol. 388, pp.860–862, 1997.
- [13] M.G. Cascone, B. Sim, D. Sandra, "Blends of synthetic and natural polymers as drug delivery systems for growth hormone", Biomaterials, vol. 16, pp.569–574, 1995.
- [14] W.E. Hennink, C.F. Van Nostrum, "Novel crosslinking methods to design hydrogels", Adv. Drug Deliver. Rev., vol. 54, pp.13-36, 2002.
- [15] H.İ. Özgündüz, "Swelling properties of semi-IPN type hydrogels containing acrylic acid-acrylamide- poly(vinyl alcohol) and lipase release behaviors", M.Sc. Thesis, Department Of Chemistry, Gazi University, pp. 1-94, 2006.
- [16] M. A. Atta and K.F. Arndt., "New crosslinkers to synthesize pH and temperature-sensitive ionic hydrogels", Macromolecules, vol. 14, pp. 671-674, 1994.



- [17] A.S. Hoffman, "Hydrogels for biomedical applications", *Adv Drug Deliv Rev.*, 43, pp.3-12, 2002.
- [18] S.N. Swami, "Radiation synthesis of polymeric hydrogels for swellingcontrolled drug release studies", Doctor of Philosophy, University of Western Sydney, New South Wales, Australia, pp. 120-149, 2004.
- [19] C.S. Brazel and N.A. Peppas, "Mechanisms of solute and drug transport in relaxing, swellable, hydrophilic glassy polymers" *Polymer*, vol. 40, pp. 3383-3398, 1999.
- [20] M.T. Ende and N.A. Peppas, "Transport of ionizable drugs and proteins in crosslinked poly(acrylic acid) and poly(acrylic acid-co-2-hydroxyethyl methacrylate) hydrogels 2diffusion and release studies". *J. Control. Release*, vol. 48, pp.47-56, 1997.
- [21] J. Ostroha, P.M., Lowman and N. Dan, "Controlling the collapse /swelling transition in charged hydrogels", *Biomaterials*, vol. 25, pp. 4345-4353, 2004.
- [22] K. Sutani, K. I. Uchida and Y. Matsubara, "Stimulus responsive drug release from polymer gel.-Controlled release of ionic drug from polyampholyte gel", *Radiat Phys Chem*, vol. 64, pp.331-336, 2002.
- [23] A.E. English, T. Tanaka and E.R. Edelman, "Polimer and solution ion shielding in polyampholytic hydrogels". *Polymer*, vol. 39, pp.5893-5897, 1998.
- [24] K. Suda, "Superabsorbent polymers and superabsorbent polymer composites"., *Science Asia*, 33(1), pp. 39-43, 2007.
- [25] D. Hunkeler, "Synthesis and characterization of high molecular weight water-soluble polymers", *Polym Int*, vol. 27, pp. 23-33, 1992.
- [26] N. Watanabe, Y. Hosoya, A. Tamura, H. Kosuge, "Characteristics of water-absorbent polymer emulsions", *Polym Int*, 30, pp. 525-531, 1993.
- [27] İ. Bayraktar, Synthesis, "Characterization And Investigation of Adsorption Properties Of Magnetic Hydrogels", M.Sc. Thesis, Department Of Chemistry, Adnan Menderes University, 2013.
- [28] T.R. Hoarea, D. S. Kohaneb, "Hydrogels in drug delivery: Progress and challenges", *Polymer*, vol. 49(8), pp. 1993-2007, 2008.
- [29] Contact Lens Imagine, <http://www.medikalakademi.com.tr/goz-kontakt-lens-bagli-komplikasyon-mikrobiyal-keratitler/>
- [30] Smart Gel Imagine, <http://m.aliexpress.com/popular/male-height.html>
- [31] Hydrogel Bead, http://tr.123rf.com/photo_15536845_kahverengi-hidrojel-toplar-s%C3%BCper-emici-polimer-bir-bardak-pothos-the-devil-s-ivy.html
- [32]<http://www.cosmoactive.com/?portfolio=3-custom-post-types>
- [33] Hydrogel Adhesive Plaster, http://tr.hartmann.info/images/5-Dermaplast_Hydro.pdf
- [34] Smart Hydrogel Surgery Plaster <http://www.webmasto.com/mit-muhendisleri-akilli-yara-bandi-gelistirdi>