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Review

Classification, processing and application of hydrogels: A review

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ABSTRACT

This article aims to review the literature concerning the choice of selectivity for hydrogels based on classification, application and processing. Super porous hydrogels (SPHs) and superabsorbent polymers (SAPs) represent an innovative category of recent generation highlighted as an ideal mould system for the study of solution-dependent phenomena. Hydrogels, also termed as smart and/or hungry networks, are currently subject of considerable scientific research due to their potential in hi-tech applications in the biomedical, pharmaceutical, biotechnology, bioseparation, biosensor, agriculture, oil recovery and cosmetics fields. Smart hydrogels display a significant physiochemical change in response to small changes in the surroundings. However, such changes are reversible; therefore, the hydrogels are capable of returning to its initial state after a reaction as soon as the trigger is removed.

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1. Introduction

A three dimensional network of polymers made of natural or synthetic materials possessing high degree of flexibility due to large water content is called hydrogels. Under physiological conditions, they are able to retain a large amount of water or biological fluids and are characterized by a soft rubbery consistency similar to living tissues, making them an ideal substance for a variety of applications. Hydrogels with characteristic properties such as desired functionality, reversibility, sterilizability and biocompatibility meet both material and biological requirements to treat or replace tissues and organs, or the function of living tissues, as well as to interact with the biological system [1–3]. Hydrogels have been found in nature since life on Earth. Bacterial biofilms, which are hydrated extracellular matrix components, and plant structures are ubiquitous water swollen motifs in nature. Gelatine and agar were also known and used for various applications early in human history, but the modern history of hydrogels as a class of materials designed for biomedical applications can be accurately traced. In 1936, DuPont's scientists published a paper on the recently synthesized methacrylic polymers. In this paper, poly (2-hydroxyethyl methacrylate) (polyHEMA) was mentioned [4]. It was briefly described as a hard, brittle and glassy polymer, and was clearly not considered of importance. After that paper, poly HEMA was essentially forgotten until 1960. Wichterle and Lim [4] described the polymerization of HEMA and crosslinking agents in the presence of water and other solvents. Instead of brittle polymers, they obtained soft, water swollen, elastic and clear gel. This innovation led to the modern field of biomedical hydrogels, as we know them today. After that, the number of hydrogel formulations steadily grew over the years.

Problems like less solubility, high crystallinity, non-biodegradability; unfavourable mechanical and thermal properties, unreacted monomers and the use of toxic crosslinkers are the limitations of the hydrogel technology. Therefore, the development of these properties with new ideas would be possible with the combination of natural and synthetic polymers with pre-determined characteristics like biodegradation, solubility, crystallinity and biological activities. Hydrogels do not disintegrate during swelling, thanks to their crosslinked structure. Crosslinking may take place in two environments: in vitro, during the preparation of a hydrogel or in vivo (in-situ), after the application at a precise location of the human body. To initiate chemical crosslinking, it is necessary to introduce a low molecular weight crosslinking agent together with a polymer into the reaction mixture. In the absence of crosslinking points, the hydrophilic linear polymer chains dissolve in water due to the polymer chain and water thermodynamic compatibility. Nevertheless, in the presence of crosslinking points, solubility is counterbalanced by the retractive force of the elasticity of the crosslinking points in the network. When these forces become equal, then swelling reaches an equilibrium [5]. The hydrophilicity of the network is due to the presence of hydrophilic groups such $–NH_2$, –COOH, –OH, $–CONH_2$, –CONH–, and $–SO_3H$, capillary effect and osmotic pressure [6]. The chemical and physical crosslinking points maintain the 3D structure of hydrogels in the swollen state. In chemical crosslinking, the polymer chains are covalently bonded via a crosslinking agent, where in physical crosslinking the hydrogels possess physical domain junctions, hydrogen bonding, hydrophobic interaction, ionic complexation, which allows solvent casting, post process bulk modification, ease of fabrication, reshaping, biodegradation and non-toxicity showing better properties, which chemically crosslinked hydrogels lack [7].

Gibas and Janik [8] reported that the swelling of hydrogels is a complex process comprising of a number of steps. In the first step, the polar hydrophilic groups of the hydrogel matrix are hydrated by water, which appears in the form of primary bound water. In the second step, the water also interacts with the exposed hydrophobic groups, which appear in the form of secondary bound water. The primary