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Hydrogel System: An Approach for Drug Delivery Modulation

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Introduction

The controlled site-specific administration of therapeutics within the body is possible through design and development of novel drug delivery systems. The delivery vehicles to be administered should be capable of releasing drug to the prerequisite site at a predetermined time and rate. It is also essential for a system to avoid the biodegradation with absolute drug release and need to remove the vehicle at the end of its useful lifetime. The carrier system should have ability to address these requirements and in addition should exhibit good biocompatibility, tunable network structure to control the diffusion of drug and, tunable affinity for drugs. Hydrogel systems are deemed to have all such properties and offer particular interest for drug delivery applications. The specific and peculiar properties of these systems gained much attraction in the development of controlled drug release formulations. In addition, these systems can also be designed and tuned to give controlled, pulsed, and stimuli responsive drug release profiles in a variety of biological sites.

Hydrogels have gained particular interest in their use in drug delivery applications mainly due to their unique physical properties such as highly porous structure which permits loading of drugs into the gel matrix and subsequent drug release. Hydrogels are three-dimensional, cross-linked networks of water-soluble polymers [1-4] can be made from water-soluble polymer. Furthermore, hydrogel based formulations can be fabricated in a variety of physical forms, including slabs, beads, microstructures, nanostructures, coatings, and films. As a result, hydrogels are commonly used in clinical practice and experimental medicine for a wide range of applications, including tissue engineering and regenerative medicine [5], diagnostics [6], cellular immobilization [7], separation of biomolecules or cells [8], and barrier materials to regulate biological adhesions [9]. Most of the polymers are derived from renewable natural resources which demonstrate a large variety of structures, different physiological functions made them to utilize in tissue engineering field due to their pseudoplastic nature, gel forming ability, binding nature and biodegradability. Few hydrogels formed by such polymers can respond to external stimuli are used to design stimuli responsive drug delivery systems. The high water content and soft consistency of hydrogels resembles natural tissues and therefore they act as natural living tissues. In addition, the above nature of hydrogels are useful in their applications in the preparation of contact lenses, linings for artificial hearts, materials for artificial skin, membranes for biosensors and drug delivery devices [10] Over the last three decades, much attention was paid on various stimuli responsive polymeric hydrogels. Specific internal or external stimuli are able to dramatically change the physicochemical properties such as swelling nature, network structure, permeability or mechanical strength of hydrogel matrices [11] Stimuli based hydrogels are highly sensitive to both internal and external changes in the environment and have been used as biosensors, superabsorbent polymers, and targeted, bio- and muco- adhesive drug delivery devices. The drug release profile of such systems is mainly based on swelling nature in response to either stimulus. The ability of these systems to exhibit rapid changes in their swelling behavior and pore structure in response to changes in environmental conditions lend to these materials favorable characteristics as carriers for delivery of bioactive agents, including peptides and proteins. This type of behavior may allow these materials to serve as self-regulated and pulsatile drug delivery systems [12] Hydrogels generally have been used to deliver hydrophilic, small-molecule drugs which have high solubility in both the hydrophilic hydrogel matrix and the aqueous solvent swelling the hydrogel. However, this is not suitable in the case macromolecular drugs such as proteins, peptides, etc. which have diffusive limitations to their partitioning into a hydrogel phase. Macromolecular drug uptake is typically restricted by their diffusion payload through the hydrogel network and thus can be addressed at least partially by engineering the pore size of hydrogels.

Hydrogels are extremely useful in biomedical and pharmaceutical applications especially these are considered to be excellent candidates for controlled drug release systems, bioadhesive or targetable devices and, self-regulated release formulations. Based on the route of administration, hydrogel-based devices can be used for oral, nasal, ocular, rectal, vaginal, epidermal and subcutaneous applications. Controlled-release systems are meant to provide the drug at a predetermined way within the body to fulfill the specific therapeutic needs. Controlled drug delivery can be used to achieve sustained constant concentration of drug therapeutically with minimum fluctuations, predictable and reproducible release rates over a long period of time, protection of drugs which have short half-time, optimizing the therapy, patient compliances through minimizing the side effects and frequent dosing, and drug stability. Oral administration of hydrogels has been considered to be most convenient route among all other and different types of hydrogels can be used for delivery of drugs to certain areas in the gastrointestinal tract ranging from the oral cavity to the colon.

Conclusions and Future Trends

Hydrogel systems being biocompatible and biodegradable in nature have been used in the fabrication of biomedical and nanobiotechnological products and have excellent applications in the field of controlled drug delivery as well. This is the reason because these tunable biomedical devices are gaining attention as smart and intelligent drug carrier systems. Hydrogel system as a drug delivery vehicle has been witnessed significant progress in improving its properties, range of bioactive compounds and kinetics which can be achieved. However, improving the clinical applicability of these systems remained with several challenges. In addition, invention of precise approaches for

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cross-linking the system to tune up release mechanism and minimize in vivo toxicity would further expand the applications of this system. It is also essential to improve the stability of more sensitive macromolecules such as proteins, antibodies, or nucleic acids when they are loaded in hydrogel system. Rightful usage of hydrogels and sensitive polymers with advanced knowledge in biotechnology and nanotechnology field is an important area with significant potential that remains to be fully investigation. There is also a scope for the pharmaceutical scientists to utilize variety of biomaterials obtained through advancement in the areas of clinical medicine, materials science and engineering. This aspect may also create an opportunity for individual multidisciplinary scientists to engaged in and can accelerate the advance of biomaterials and create new applications for these materials in medicine and drug delivery areas. Perhaps, future advances in these challenging areas would greatly expand the potential of hydrogel-based drug delivery systems.

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