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Cyclodextrin Glycosides as Materials for Removal of Pathogenic Materials from the Human Environment

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Abstract

Cyclodextrins provide an intriguing agent system for the removal of a host of materials from aqueous media in order to prevent pathogens from affecting humans. In the current effort cyclodextrins have been chemically modified such that they may be used efficaciously for the removal of a wide range of harmful materials from aqueous environments impinging on human activities. Among these modifications are those that involve selective targeting of the upper and lower rims of the cyclodextrin species for selective encapsulation of organic chemical toxins of appropriate size, shape, and hydrophobicity, as well as the generation of hyperbranched polymers from the cyclodextrins for enhanced encapsulation, and the functionalization of cyclodextrins for the facilitated destruction of pathogenic bacterial agents. Utility of the constructed cyclodextrin materials for a variety of situations is considered.

Keywords: Hydrophobic agents; Osmosis; Hydrolysis; Purification

Introduction

Efforts of our laboratories at Queens College over the past several years have resulted in the development of processes that render a wide range of surfaces antibacterial and antifungal, and in certain instances, antiviral [1-16]. Specific application of these efforts to diverse surfaces can greatly alleviate health difficulties that have arisen recently, primarily owing to resistant bacteria and fungi being transmitted from person to person indirectly.

In our current effort we are concerned with the development of systems that will be of use for the purification of waste-water, that from rain run-off from land into aqueous basins or waterways, as well as that from sewage overflow. While our prior developed approaches remove bacteria and fungi from such aqueous systems (as noted in the references above, and are currently being implemented in commercial systems) it is also necessary to remove organic contaminants. Our approach to various surfaces serving as prophylactic agents for preventing bacterial and fungal infections has been reported in a series of publications as well as numerous patents.

Results and Discussion

For the removal of organic contaminants from aqueous systems, we have chosen to use cyclodextrin derivatives. Since simple cyclodextrins are significantly soluble in aqueous systems, we have chosen to use polymers derived from the simple cyclodextrins which would be of sufficient size to be water insoluble, yet have capability of trapping hydrophobic organic contaminants within the torus of the cyclodextrin. Polymers prepared as we have chosen would be hyperbranched polymers, a characteristic that would decrease their water solubility [17].

Hyperbranched polymers are those derived from monomer units of the following type, with one particular type of coupling site that can interact (couple) with any one of several sites that differ from each other minimally, or not at all.

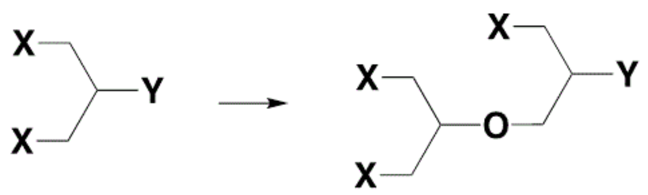

Figure 1: Monomer units interaction.

In general: Monomer units of this type can connect in a variety of ways for site **Y** interacting with one of the sites **X** (Figure 1) to provide hyperbranched polymers as shown here (Figure 2), where **O** represents the new junction unit between the starting monomers of partial polymers. In this way water insoluble polymers of cyclodextrins (locations indicated by the branching points of the polymer) can be generated providing numerous sites to serve for the inclusion of hydrophobic organic materials.

The greater the degree of branching and extension, the lower the solubility in aqueous (and other) systems. However, with cyclodextrins so joined, the inner hydrophobic region remains available for trapping organic materials from the aqueous surroundings, thus removing them from the water. The procedure for the generation of the hyperbranched polymers of cyclodextrin species is shown below (Figures 3 and 4).

MALDI-TOF mass spectrometry measurements (Matrix Assisted Laser Desorption/Ionization Time-Of-Flight) indicate a mixture of hyperbranched polymers of size principally from 3-6 cyclodextrin units. Other types of dico-ordinating linker units have been employed by others to join individual cyclodextrin units. These have usually been moderately reactive species involving ester linkages that are subject to relatively facile hydrolysis [18]. Our current effort employs ether

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linkages that are far less susceptible to hydrolysis than such ester linkages.

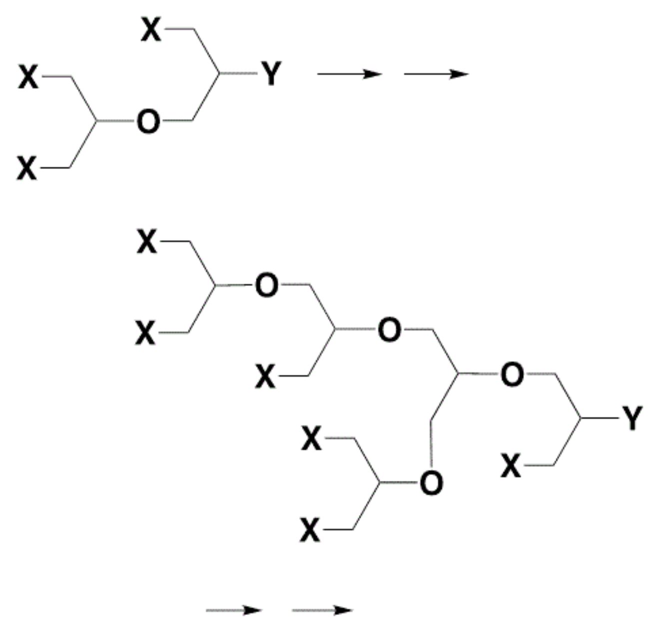

Figure 2: Hyperbranched Polymer.

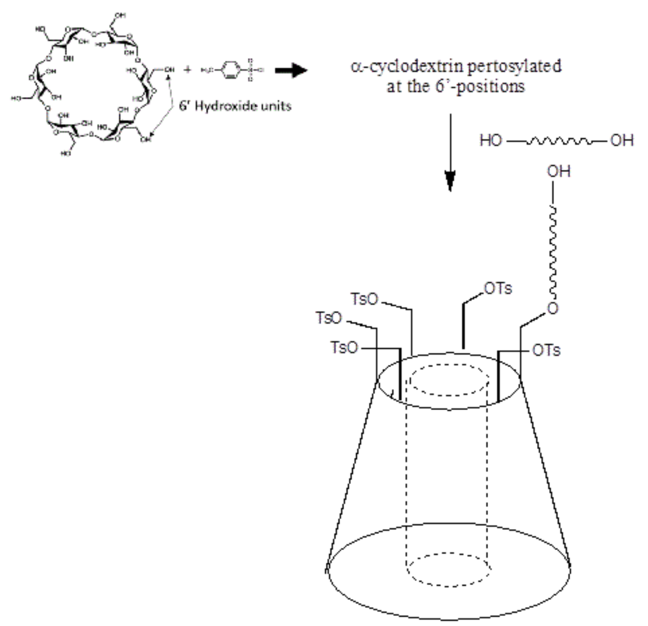

Figure 3: Procedure for the generation of the hyperbranched polymers of cyclodextrin species.

Studies using aqueous media in which the hyperbranched cyclodextrin polymers were insoluble but in which naphthalene was slightly soluble were performed to determine the ability of the polymers to include the naphthalene and remove it from solution (Figure 5). It was determined that for added solid polymer (average of 3-6 cyclodextrin units per polymer unit using ten-carbon chains as linkers) comparative molar amounts of naphthalene could be removed from a solution before build-up of naphthalene occurred (determined by HPLC-High Performance Liquid Chromatography).

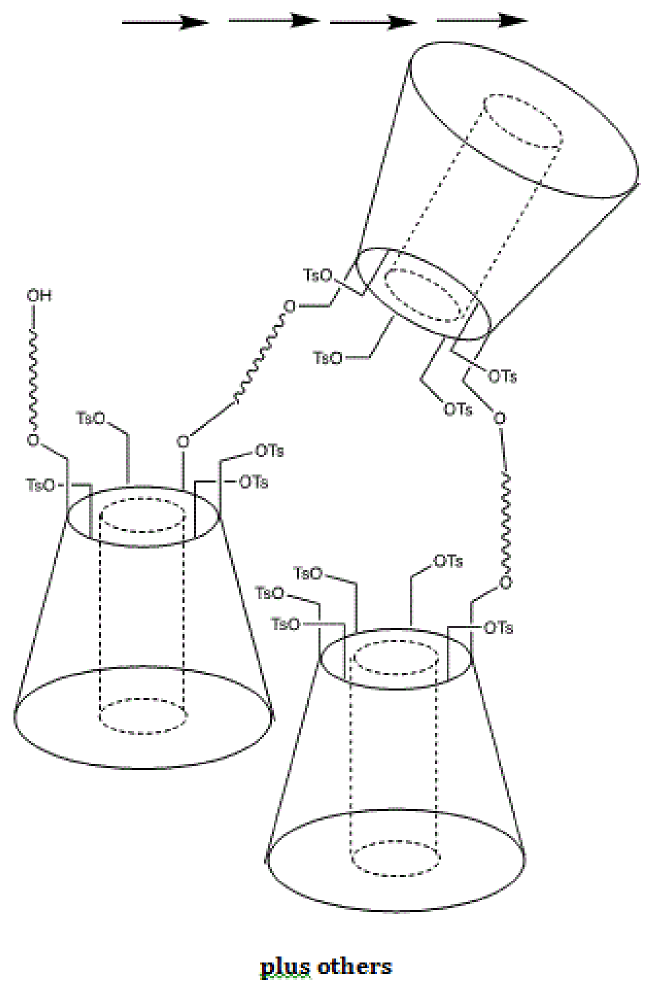

Figure 4: Generation of the hyperbranched polymers of cyclodextrin species.

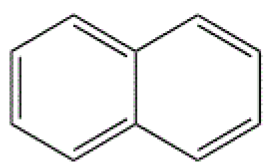

Figure 5: Naphthalene was used as a test for organic contaminants to be captured by the hyperbranched cyclodextrin polymer.

Conclusion

Thus, the hyperbranched polymer of cyclodextrin is performing well for the purification of water from the contaminating organic material. We are continuing to be engaged in the investigation of the range of organic contaminants which can be removed from aqueous media. It should be noted that use of such cyclodextrin derivatives will render unnecessary other more energy demanding approaches toward the removal of organic contaminants, such as involving evaporation, osmosis, and extraction. Removal by filtration, regeneration in a separate site, and reuse of the cyclodextrin derivatives will accommodate the suitable purification of the aqueous medium. Further, the use of oxidizing chemicals (such as chlorine), for which there is not only a financial cost of production and continual use, but an energy cost for that production and use, will not be necessary as the passive interaction of the aqueous material to be purified with the treated surface of the active agent will render the aqueous medium free of both Gram +ve and Gram –ve bacteria as well as numerous viral species [13-16].

In addition to continuing work using the cyclodextrin as noted, work is continuing with longer and shorter linkers between the cyclodextrin units, as well as with different sizes of cyclodextrins. (Shorter units introduce a difficulty with cyclodextrin units being too close for efficient guest accommodation, while longer are less efficient in preparation. Optimal size cyclodextrins are being studied for inclusion of other sizes of pollutants.) Work is also continuing on local environmental sites troubled with organic pollutants (Flushing Bay, NYC, USA).

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