Gamma radiation modified CMC-based hydrogels: Behaviour of heavy metal ion removal from aqueous solution

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Introduction

Nowadays, many works on the treatment of heavy metal ions have been applied such as ion exchange, chemical precipitation, membrane filtration and solvent extraction. However, the main disadvantages of these methods are no selectivity toward metal ions (ion-exchange); requirement of special pre-treatments before heavy metal ions precipitation (chemical precipitation); the high operational cost or loss of material through phase disengagement (membrane filtration), and disposal of large amount of extractant (solvent extraction)[1].

Meanwhile, hydrogels have been proved as potential candidates for the removal and recovery of heavy metal ions due to the presence of proper functional groups that are capable for selective interaction with metal species. Recycling of metal absorbed-hydrogels is very simple and economical. Through a desorbing step by elution using nitric acid, Hara et al.[2] found that heavy-metal-loaded-hydrogel can achieve almost complete desorption and cheaply be regenerated.

Carboxymethyl cellulose (CMC)-based hydrogel, one type of popular adsorbents has attracted substantial concern in decades because it is cheap, renewable, less toxic and high reusable. Our study also utilizes this hydrogel after modifying it with multi-functional groups to improve its metal adsorption capacity from aqueous solution.

Experimental

Modified CMC-based hydrogels were prepared by the following procedure. The sets of aqueous solution of 20 wt% CMC and Styrene sodium sulfonate (SSS) in paste-like state with different added more components such as Bis[2-(Methacryloyloxy)Ethyl] Phosphate, (BMEP) or carboxymethyl chitosan (CMCts) were into polypropylene tubes. Each mixture was centrifuged at 10^4 rpm for at least 5 hours to remove tiny bubbles and then was γ-irradiated in 60-kGy-dose at atmosphere condition. After washing with distilled water to remove all un-reactants, the modified CMC hydrogels were characterized by Fourier transform infrared (FTIR), Energy-dispersive X-ray spectroscopy (EDS) and Scanning electron microscopy (SEM). Batch adsorption experiments were carried out to compare multi element removal capacity (Eq. 1) of the studied CMC-based hydrogels. Some conditions including different pH and weight of hydrogels also were defined optimum reaction conditions. All tests were carried out at least three times and the averages were used in the analysis.

$$Removal\ (\%) = \frac{C_0 - C_f}{C_f} \quad (Eq.1)$$

where C_0, C_f (μg/L) are the initial and final concentration of metal ion in solution, respectively.

Results and Discussion

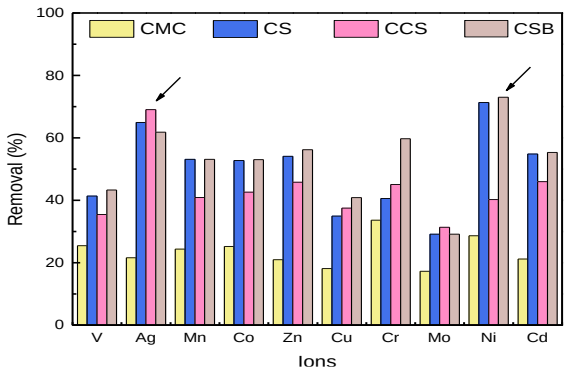

Fig. 1. The metal removal (%) of CMC vs. modified CMC–based hydrogels with their abbreviated names: **CMC** (carboxymethyl cellulose only); **CS** (CMC + SSS); **CCS** (CMC + CMCts + SSS); **CSB** (CMC + SSS + BMEP)

The presence of different functional groups on modified CMC-based hydrogel showed the clear effect on the metal removal (%), as shown in Fig. 1. For original CMC hydrogel, metal ions in aqueous solution were uptake low, < 50%. However, when introducing of SSS, CMCts and BMEP to CMC backbone, most of metal removed significantly by modified CMC hydrogel (> 50%), especially for Ni and Ag ions. The metal ion selectivity efficiency of each gel might depend on strong ionic groups such as $–PO_4^-$, $–SO_3^-$, $–NH_3^+$ and $–COO^-$ groups present on hydrogel network and lead to higher binding affinity with metal ions. Other results will be presented at the meeting.

Acknowledgment

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References

1. Reddy NS et al. *Polymer Hydrogels: Recent Advs. in Toxic Metal Ion Removal & Anticancer Drug Delivery Applications.*

2. Hara K et. al. A possibility of heavy-metal recycling by utilizing hydrogels. *Trans Mater Res Soc Japan*. 2010;(20):23-28.