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Removal of Heavy Metals by Ultrafiltration Assisted with Chitosan or Carboxy-Methyl Cellulose

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Abstract : Treatment of heavy metal-contaminated industrial wastewater has become a major challenge over the last decades. Conventional processes for the treatment of metal-containing effluents do not always simultaneously satisfy both legislative and economic criteria. In this context, coupling of processes can then be a promising alternative to the conventional approaches used by industry. The polymer-assisted ultrafiltration (PAUF) process is one of these coupling processes. Its principle is based on a sequence of steps with reaction (e.g., complexation) between metal ions and a polymer and a step involving the rejection of the formed species by means of a UF membrane. Unlike free ions, which can cross the UF membrane due to their small size, the polymer/ion species, the size of which is larger than pore size, are rejected. The PAUF process was deeply investigated herein in the case of removal of nickel ions by adding chitosan and carboxymethyl cellulose (CMC). Experiments were conducted with synthetic solutions containing 1 to 100 ppm of nickel ions with or without the presence of NaCl (0.05 to 0.2 M), and an industrial discharge water (containing several metal ions) with and without polymer. Chitosan with a molecular weight of 1.8×105 g mol^{-1} and a degree of acetylation close to 15% was used. CMC with a degree of substitution of 0.7 and a molecular weight of 9×105 g mol^{-1} was employed. Filtration experiments were performed under cross-flow conditions with a filtration cell equipped with a polyamide thin film composite flat-sheet membrane (3.5 kDa). Without the step of polymer addition, it was found that nickel rejection decreases from 80 to 0% with increasing metal ion concentration and salt concentration. This behavior agrees qualitatively with the Donnan exclusion principle: the increase in the electrolyte concentration screens the electrostatic interaction between ions and the membrane fixed the charge, which decreases their rejection. It was shown that addition of a sufficient amount of polymer (greater than 10^{-2} M of monomer unit) can offset this decrease and allow good metal removal. However, the permeation flux was found to be somewhat reduced due to the increase in osmotic pressure and viscosity. It was also highlighted that the increase in pH (from 3 to 9) has a strong influence on removal performances: the higher pH value, the better removal performance. The two polymers have shown similar performance enhancement at natural pH. However, chitosan has proved more efficient in slightly basic conditions (above its pKa) whereas CMC has demonstrated very weak rejection performances when pH is below its pKa. In terms of metal rejection, chitosan is thus probably the better option for basic or strongly acid (pH < 4) conditions. Nevertheless, CMC should probably be preferred to chitosan in natural conditions (5 < pH < 8) since its impact on the permeation flux is less significant. Finally, ultrafiltration of an industrial discharge water has shown that the increase in metal ion rejection induced by the polymer addition is very low due to the competing phenomenon between the various ions present in the complex mixture.

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