Removal of zinc ions from aqueous solution using micellar-enhanced ultrafiltration at low surfactant concentrations

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Abstract

Micellar-enhanced ultrafiltration (MEUF) of zinc ions (Zn^{2+}) from aqueous solutions using single anionic surfactant sodium dodecyl sulphate (SDS) at low critical micelle concentrations (cmc) (0.2×cmc – 3×cmc) was investigated. When the initial SDS concentration was below the cmc, unexpectedly high rejection (97.5%) was obtained due to concentration polarisation occurring near the membrane-solution interface. Based on this mechanism, the true rejection of the solute is no longer a function of the initial SDS concentration in the bulk solution but a function of the SDS concentration at the concentration polarisation layer. The removal of Zn^{2+} at low Zn^{2+} feed concentrations was very efficient. The characteristics of Zn^{2+} ion adsorption to surfactant micelle were also studied. The Langmuir model could be used to elucidate the Zn^{2+} adsorption isotherm to the SDS micelle. The study demonstrates the potential practicality of the MEUF technique for the removal of heavy metal ion pollutants such as Zn^{2+} at low surfactant concentrations.

Keywords: micellar-enhanced ultrafiltration, concentration polarisation, sodium dodecyl sulphate, micelle, Langmuir isotherm

List of symbols

R	percent rejection (%)
C	concentration of the Zn^{2+} (mg/ℓ)
J	permeate flux ($m^3/m^2 \cdot s$)
Δp	trans-membrane pressure (Pa)
R_m	hydraulic resistance of membrane (m^{-1})
R_f	secondary resistance of the membrane (m^{-1})
µ	viscosity coefficient (Pa·s)
α	volume concentrated ratio
β	concentration concentrated ratio
V	volume (ℓ)
K	adsorption equilibrium constant (ℓ/mmol)
q_{max}	maximum amount of adsorbed Zn^{2+} (mmol/g)
q_e	amount of adsorbed Zn^{2+} at equilibrium (mmol/g)
C_e	concentration of Zn^{2+} in the bulk liquid phase at equilibrium (mmol/ℓ)

Subscripts

i	initial feed solution
p	permeate
r	retentate
w	water
s	solution

Introduction

Heavy metal water pollution is a serious environmental problem in the world. The metal ions are non-biodegradable, highly toxic and may have a potentially carcinogenic effect. If directly discharged into the sewage system, they may seriously damage the operation of biological treatment plants. Wastewater containing dissolved metal ions such as zinc, cadmium, nickel and copper originate from a variety of sources such as metal mine-tailing leachate, refineries, semi-conductor manufacturing, battery, abandoned metal mines and metal plating industries. At present, the traditional techniques for the removal of metal ions from wastewater that are in practice include adsorption, extraction, precipitation, electrolytic method, ion exchange method, and distillation. However, these techniques have their own disadvantages, such as inconvenient operation, secondary pollution of deposition, loss of expensive chemicals, difficulty in recovering metal ion, strong pH sensitivity, incapable of reducing metal ions concentration to the levels required by law and so on.

Micellar-enhanced ultrafiltration (MEUF) as a surfactant-based separation process is an effective technique to remove almost all the toxic metal ions and/or soluble organic solutes from aqueous solutions (Baek et al., 2003; 2004; Gzara et al., 2001; 2000; Juang et al., 2003; Kim et al., 2003; Liu et al., 2004; Tung et al., 2002; Yurlova et al., 2002). In the MEUF process, the surfactant is added to the polluted aqueous solution containing metal ions and/or organic solutes. The surfactant forms micelles which are charged spherical aggregates containing 50 to 150 surfactant molecules at a concentration higher than its critical micelle concentration (cmc) and above its Kraft point temperature (Gzara and Dhahbi, 2001). The metal ions are adsorbed on the surface of the oppositely charged micelles by electrostatic attraction. The organic solutes are solubilised in the micelles interior by ion-dipole interaction. Then the micellar solution passes through an ultrafiltration membrane with a small enough pore size to reject the micelles containing the contaminants. As micelles are rejected, the adsorbed metal ions and the solubilised organic solutes will also be rejected. The un-adsorbed metal ions or un-solubilised organic solutes and surfactant monomers

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