Removal of benzalkonium chloride by polymeric adsorbents

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1. Summary

Removal of benzalkonium chloride (BKC) from aqueous streams by polymeric resins XAD-7 and XAD-16 was investigated. Adsorption equilibrium isotherms of BKC from water were measured in a batch adsorber at different temperatures and ionic strengths of the external phase. In addition, the influence of an organic solvent (ethanol) on the phase equilibrium was studied. The experimental data was correlated with the Langmuir isotherm, and thermodynamic parameters for adsorption process were determined. Mass transfer kinetics were investigated in a batch adsorber and correlated with a Fickian diffusion model. Finally, removal of BKC in an adsorption column and regeneration of the column was investigated. It was found that a three-step process is necessary: after break-through, the column could be efficiently regenerated only with an aqueous ethanol solution (20% – 50% EtOH), followed by a short washing stage.

Keywords: cationic surfactant, adsorption, polymer, thermodynamic parameters

2. Extended Abstract

Cationic surfactants are widely used in many industries, household products, and hospitals as bactericides. Because of their toxic properties and very large production volume, their efficient removal from wastewaters is very important.

Polymeric resins have recently been widely investigated as an alternative to activated carbon for the removal of organic pollutants from wastewater (1, 2). Their benefits include more uniform surface chemistry and pore structure as well as the possibility of regeneration under mild conditions. In this work, adsorption of cationic surfactants onto non-ionic polymeric resins is investigated by using benzalkonium chloride (BKC) as a model substance. Two types of adsorbents are used: XAD-7 is an acrylic ester polymer, whereas XAD-16 is a styrenic polymer.

Adsorption equilibrium isotherms were measured at various ionic strengths (0.1, 10 and 100 mM NaCl) and temperatures (23 ^{o}C, 37 ^{o}C and 50 ^{o}C). In addition, the influence of an organic solvent (ethanol) on the phase equilibrium was studied. Adsorption kinetics experiments were conducted in a batch adsorber at pH 5, an ionic strength of 0.1 mM NaCl, and a temperature of 23 ^{o}C.

The adsorption equilibrium isotherms were successfully correlated with the Langmuir isotherm. It was found that the adsorption efficiency was strongly dependent on the ionic strength of the external phase. Higher sorption capacity per mass (and volume) of adsorbent were obtained in the case of the XAD-16 polymer. On the other hand, adsorption capacity per surface area of adsorbent was higher in the case of XAD-7.

Considering the chemical structures of the adsorbents, it seems probable that, in the case of XAD-16, the adsorption mechanism involves hydrophobic interaction. The stronger interaction observed with XAD-7 stems most from hydrogen bounding and possibly electrostatic interaction. Thermodynamic parameters for the adsorption process were determined using adsorption equilibrium parameters calculated for different temperatures. The heat of adsorption was found to be relatively low and had a negative value, indicating that interaction between adsorbent and adsorbate molecules is physical and of exothermic nature. The adsorbed amounts were found to decrease strongly with increasing amounts of ethanol in the external phase.

Removal of BKC from aqueous streams in a single-column adsorption process was studied experimentally and by means of mathematical modeling. As expected from the batch adsorption kinetics data, intraparticle mass transfer resistance was found to be significant, reducing the working capacity of the column. Due to very high affinity of BKC towards the adsorbents, desorption was found to be not feasible by using water as the eluent. Instead, aqueous ethanol solutions (20 wt-%, 50 wt-%) were found to regenerate the column efficiently. Under typical conditions, the duration of the regeneration step was approximately 10 % of the adsorption step. A short washing step prior to the next adsorption cycle was found to be necessary.

References

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