REJECTION MECHANISM FOR ARSENATE, CHROMATE AND PHOSPHATE IONS VIA POLYACRYLONITRILE ULTRAFILTRATION MEMBRANE

ABSTRACT

The presence of heavy metals like arsenic, chromium and large amount of phosphate in aquatic source, and eventually in potable water, is a serious health issue. Membrane separation technology is a viable and reliable process engineering operation which can be applied for heavy metals and inorganic pollutant removals from aquatic stream. Conventional membrane technologies like Reverse Osmosis and Nanofiltration require high operating pressure for water treatment as compared to Ultrafiltration membrane.

The present study was to investigate the polyacrylonitrile (PAN) based UF membrane for effective and selective removal of arsenic, chromium and phosphate from water. Applicability of polyacrylonitrile (PAN) based ultrafiltration (UF) membrane for effective arsenic, chromium and phosphate removal was established for the first time. The removal of anions (arsenate, chromate and phosphate) from potable water using surface modified PAN ultrafiltration membranes was carried out with plate and frame module in cross-flow mode. Ultrafiltration membranes were subjected to anionic concentrations in the feed ranging from 250 ppb to 1000 ppm to test its efficacy. The effects of physical and engineering parameters (pressure, temperature and cross flow velocity) as well as chemical parameter (ions concentration and pH) on the rejections of anions were studied as a function of time. Variation of feed pH played a vital role on ions transport through the membrane. More than 95% rejection of arsenate, chromate and phosphate ions were achieved separately for each anions at pH ≥ 7. The concentration polarization was negligible at low feed concentration (≤ 150 ppm).

The rejection mechanism of anions was strongly dependent on Donnan exclusion principle. Generally, higher rejection % of arsenate, chromate and phosphate ions (≥ 92%) were obtained with high Donnan potential value (~ 20 mV). Moreover, Donnan potential was vital at feed concentrations (1 ppm to 150 ppm) and it was negligible at very low feed concentration (<<1000 ppb) and again it became weaker at very high concentration (≥ 500 ppm).

In multicomponent system, the mixture of arsenate, chromate and phosphate ions showed more than 92% for feed concentration of 50 ppm each. In addition, heavy metals (arsenate, chromate) and phosphate removal using PAN ultrafiltration, were effective (≥ 97%) at low pressure operation compared to nanofiltration (NF) membranes. The surface modified membrane were also subjected to high operating transmembrane pressure for the effective removal of arsenic, chromium and phosphate ions from potable water. The membrane showed more than 94% rejection efficiency of divalent anions at the transmembrane pressure of 10 bar. The surface modified PAN membrane did not show any fouling and would work for a long time; gave almost 100% rejections for ppb level concentration of arsenate and ppm level of chromate and phosphate ions in the feed. However, due to concentration polarization effect on the membrane surfaces, the rejection % of arsenate, chromate and phosphate ions were reduced to 87 %, 85% and 89% respectively at 12 bar of transmembrane pressure.

The Donnan steric-partitioning pore model incorporated with dielectric exclusion (DSPM-DE) was applied to evaluate the ions transport through the membrane as a function of flux by using optimized model parameters like feed concentration, the membrane active layer thickness, the effective volumetric charge density and membrane permeability. The modified DSPM DE model was applied for theoretical calculation of flux and rejection of arsenate ions in the case of PAN membrane. The model also applied for chromate and phosphate ions rejection through the membrane. The comparison of simulated and experimental rejection data showed that DSPM-DE model fully predicted the tendencies and pattern of ionic rejection as a function of flux.