Modeling crossflow filtration: Effect of shear on particles-enriched polarization and cake layers

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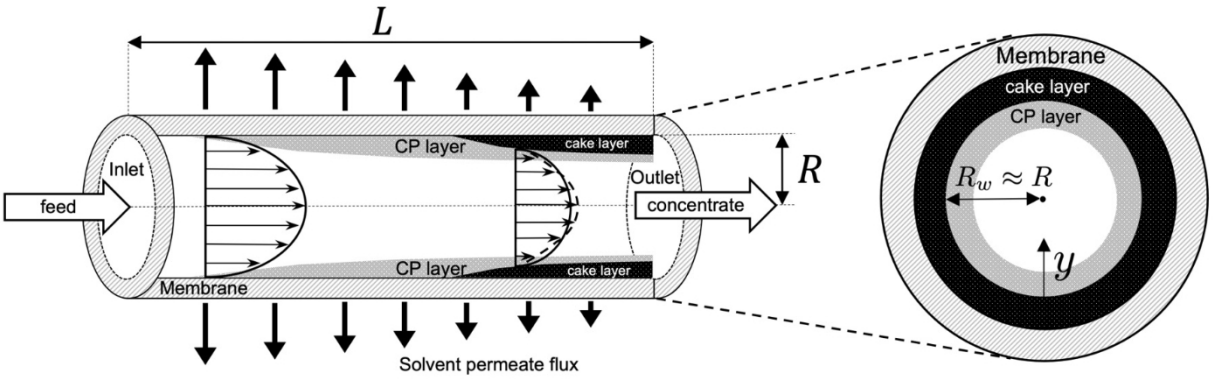
Crossflow filtration (CF) is a pressure-driven separation and enrichment process for colloidal particles, in which a feed dispersion is continuously pumped through a cylindrical membrane channel permeable only to solvent. During the filtration process, particles accumulate at the membrane, forming a fluid-like, inhomogeneous concentration polarization (CP) layer and a solid-like cake layer. Both layers tend to lower filtration efficiency by increasing energy consumption per unit of colloid concentrate. Based on a newly developed accurate semi-analytic model for CF, we determine spatially resolved flow and particle concentration profiles in the transition regime between ultrafiltration (UF) and microfiltration (MF), where shear flow effects compete with Brownian particle motion [1]. Results are presented for model dispersions of non-permeable and permeable colloidal hard spheres [2,3], accounting for the shear-rate and concentration dependencies of collective diffusion and viscosity, as well as for a thin filter cake. Shear thinning of viscosity and shear-enhanced Brownian diffusion tend to improve filtration performance by increasing the critical permeate flux and transmembrane pressure at which cake formation sets in, and by lowering the cake coverage of the membrane surface. New findings include a non-monotonic shear-rate dependency of the dispersion flow across the CP layer, and a shear-induced significant upturn of the critical permeate flux at larger shear rates. The observed upturn resolves a long-standing so-called critical flux paradox related to the UF to MF transition regime. Our presentation bridges the gap between fundamental research on shear-affected colloidal transport properties and dispersion flow, and crossflow filtration as an important technological process.



Schematic view of inside - out crossflow filtration in a cylindrical membrane channel of length L and inner radius R

References:

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