Concentration Polarization Effects In A Single Pass Membrane Module For Continuous Diafiltration

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Abstract

Concentration polarization (CP) is a common problem in membrane filtration. It is caused by the convective transport of large molecules towards the membrane surface, however while the solvent passes the membrane as permeate, the molecules are retained and accumulate at the membrane surface. The degree of accumulation is counter-acted by a diffusive flux pointing from the regions of high concentration back into the bulk solution. The usual way to limit CP is the application of so-called tangential flow filtration. In this operation mode the feed solution is pumped in parallel to the membrane surface at high speed, in order to reduce the thickness of the CP layer. Recently, we introduced an alternative way to reduce CP by designing a filtration module with two adjacent membranes confining the retentate channel and applying an alternating direction of the perfusion of permeate as inherent backflush during continuous operation (see Fig. 1). This way of operation results in a complex flow pattern and periodic accumulation and depletion of dissolved molecules at different locations of the module. Therefore, we developed a 2D COMSOL Multiphysics® model describing the time-dependent behavior of our module in order to optimize various operation conditions, such as the switching time of the perfusion direction. The poster presents how the alternating perfusion can be modelled using less common COMSOL Multiphysics® features, such as multiple steps with modified model configurations and combined solutions as well as mapping of calculated variables into other locations of the module by linear extrusion.
The model combines the physics of 'Transport of Diluted Species' with the 'Laminar Flow' physics in order to achieve the time-dependent profiles of local pressure, hydraulic permeability of membranes and varying concentrations of the retained molecule, in our case the protein bovine serum albumin (BSA). Fig. 2 presents the underlying transport behavior of BSA in the confined middle channel. The BSA in the bulk stream was deposited at the membrane surface when applying the diafiltration buffer vertically; while the compacted BSA released back into the bulk solution and accumulated gradually at the opposite membrane surface when the direction of diafiltration buffer changed. Such alternating operation in the two-membrane module system contributes to the alleviation of CP problem dramatically.
The simulated results show a good agreement with experimental results and clarify the underlying transport behavior of BSA during the quasi-stationary processing successfully. We observe a stable, wave-like, variation of the concentration of BSA in the retentate (see Fig. 3). The average concentration of BSA in the retentate flow matches the concentration in the feed stream, validating the accuracy of the calculation and that the mass balances close despite the high concentration differences along the cross-section of the flow channel.

Figures used in the abstract

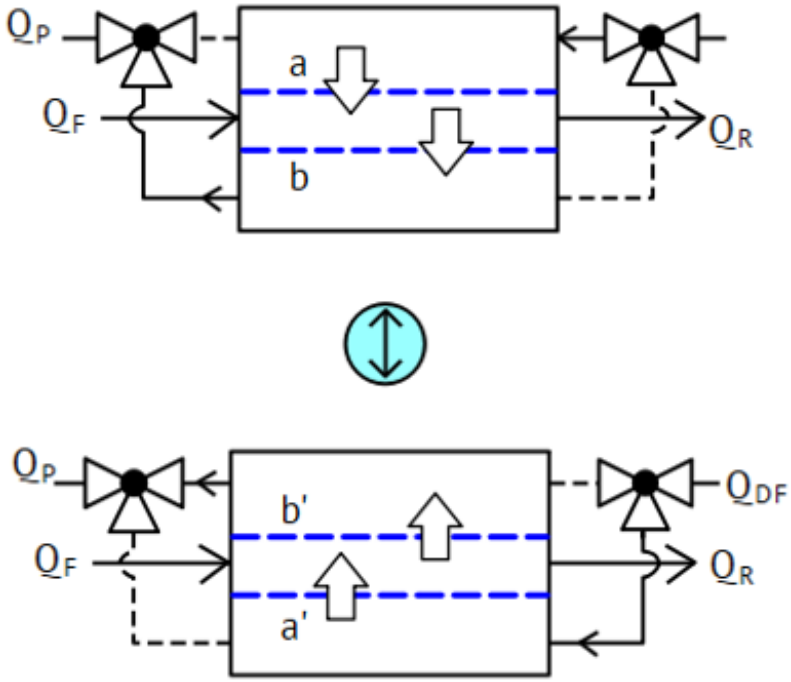

Figure 1 : Scheme of the continuous operation applying the alternating perfusion of permeates back into the middle channel.

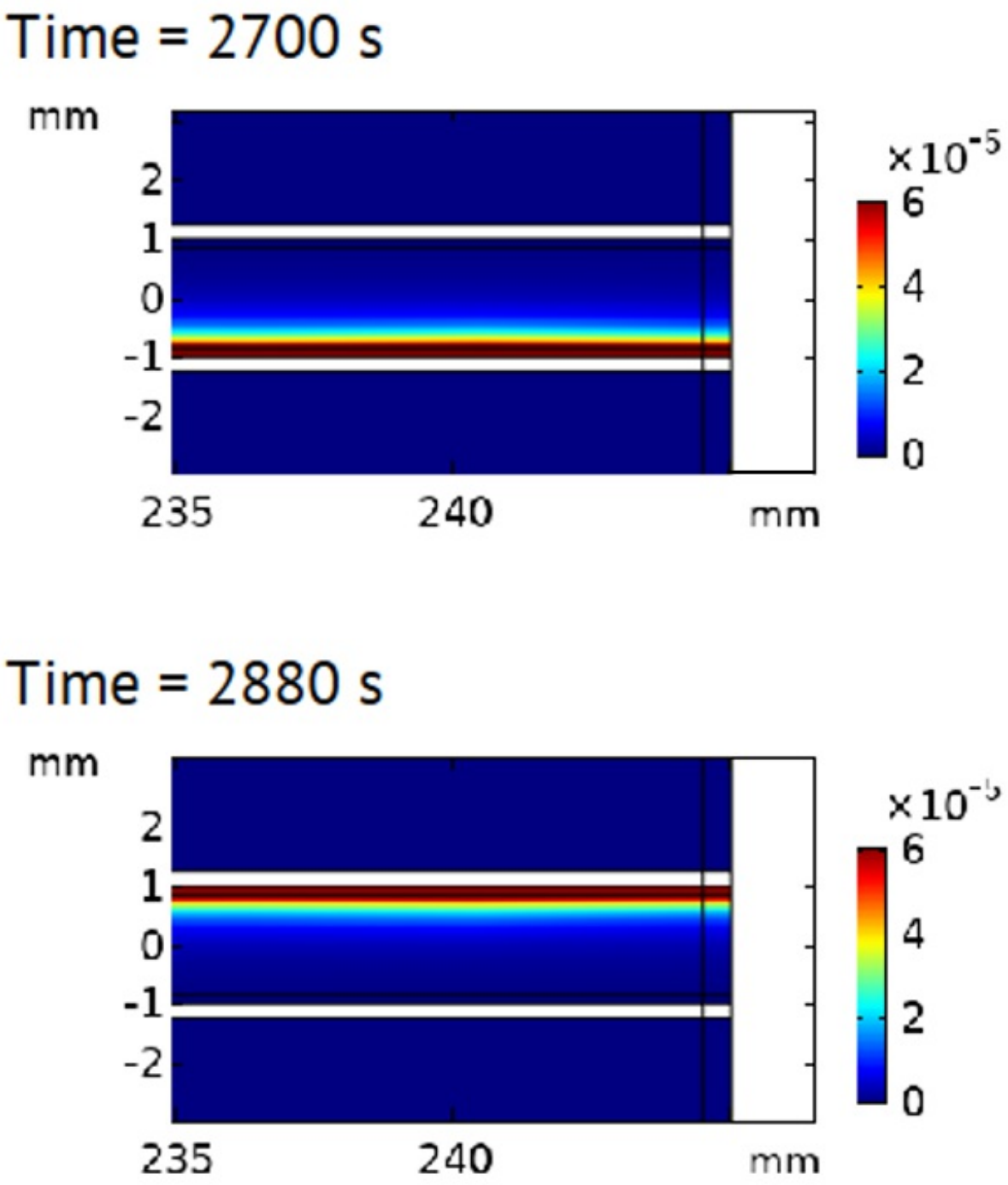

Figure 2 : Surface concentration distribution of BSA at the end section of the module before and after alternating the flow direction of the permeate.

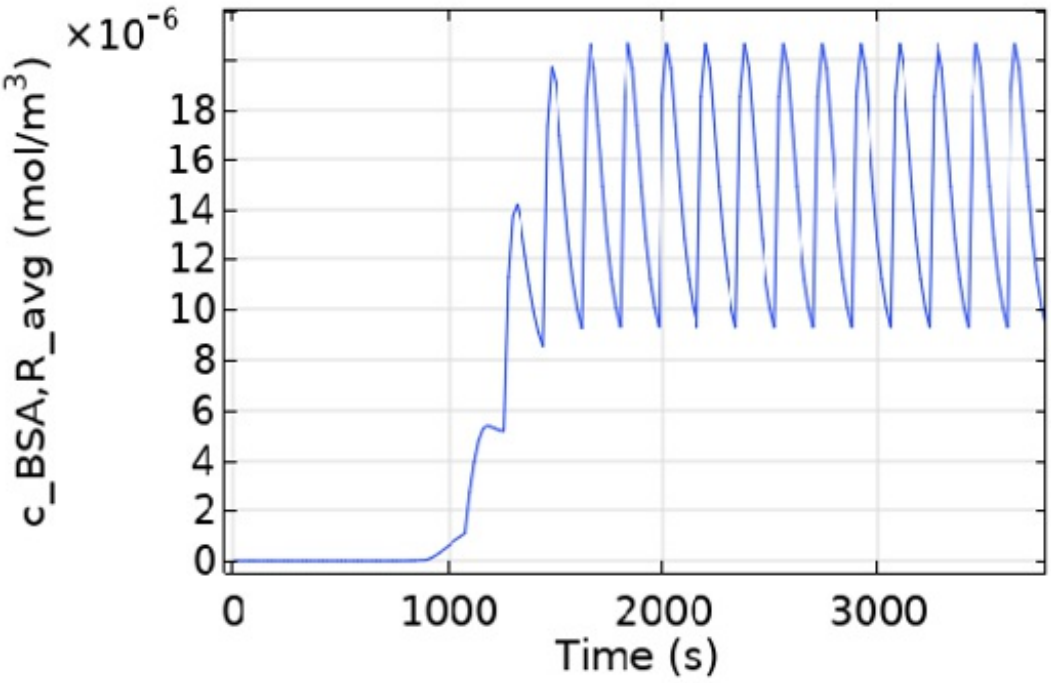

Figure 3 : Average concentration of BSA in the retentate. The effluent concentration matches the concentration in the feed stream (the blue dash line).