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Simulation Protocol for Optimization of Energy - Efficient Membrane Filtration Modules

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The aim of this project was to design a protocol for simulating fluid flow in Forward Osmosis (FO) filtration modules. This was motivated by the need for a robust tool, which could be used to determine optimal geometries for filtration modules.

FO is an osmotically driven filtration process, that relies on a large osmotic pressure difference across a semi-permeable membrane, to extract pure water from contaminated solutions. It is an emerging technology with a great number of potential applications, and unlike the broadly applied Reverse Osmosis (RO) filtration process, it requires no external pressurization, which makes it potentially more energy-effective.

In its field of research, this work stands out because it aims at analyzing the FO flow problem in 3D, whereas previous efforts have mainly been focused on one- and two-dimensional analysis. The protocol employs Computational Fluid Dynamics (CFD) methods, using the open source software package OpenFOAM, to produce simulations that replicate flow conditions inside the filtration module during operation. A previously validated CFD model, specifically developed for simulation of FO filtration in OpenFOAM, was implemented.

The protocol enables designers to "pick out" flow characteristic information such as velocity, pressure and salt concentration at every location of the module, throughout time. Moreover, it enables visual inspection of the flow conditions, which can be used to produce readily comprehensible images and animations, e.g. to communicate results to a non-scientific audience.

To illustrate its use in research, the protocol is applied to a number of ideal cases in order to determine relationships between generic parameters. Its technological practicality is furthermore demonstrated using the commercial Sterlitech CF042 module as a simulation case. The results yield unexpected relationships between generic parameters, and illustrate clearly the need for improvement of commercial FO membrane filtration modules, which should send a strong message to manufacturers and designers.