Mathematical modelling of a water filtration process based on membrane filters

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Exposition of the problem:

The use of polymeric membranes to filter waste waters is a technique widely applied by industry and municipal companies devoted to the control of the water quality.
In our context, we deal with a filtration module consisting in a pressure vessel housing some *multi-bore* fibres, namely a polymeric porous fibre holed by 7 bores along its length. The water to be filtered pass within the bores and flow through the membrane, due to the applied pressure gradient between inner and outer part of the fibre. The pollutant particles larger than the membrane pores diameter are cut off inside the channel, so that the water collected outside the fiber is cleaned.
The main problem in these filtering systems is the membrane *fouling,* namely the process making the membrane dirty. As a the matter of fact, a part of the filtered particles can attach on the inner surface of the membrane, forming a thin layer (the so-called *cake*) which eventually soils the medium and reduces the filtration efficiency. To remove this material, periodically a back wash process is imposed to the system, inverting the flux and let the clean water flow through the membrane.
Therefore, in defining a model describing the whole filtration process one has to to take into account: (i) the hydrodynamic problem, referred to the water flowing in the porous medium; (ii) the diffusion/reaction problem, referred to the particles suspended in water and attaching on the membrane.

Scheme of the work to be done:

1) Introduction of the general problem, also providing a raw analysis of experimental data. Such preliminary part is useful to focus the most important parameters to be simulated (according to the technical specifications given by the company).

2) Set up of the set of equations, and of boundary conditions, in the simplified 1D case.

3) Scaling procedure: study of the order of magnitude of the main parameters in order to: (A) introduce further simplifications to the model (if possible); (B) calculate the time scales characterizing the different processes.

4) Numerical solution of the dynamic problem referred to a single cycle filtration + back wash.

5) Provide an *average* procedure (w.r.t. spatial variables) in order to reduce the model to a system of ordinary differential equations: application of the averaged model to simulate several cycles of filtration + backwash.