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# In vitro cartilage culture: coupled flow, transport and reaction in fibrous media

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Flow and transport in fibrous media are encountered in a wide variety of domains ranging from biotechnology to filtration in chemical engineering. The context of this work is the *in vitro* cartilage cell culture on a fibrous biodegradable polymer scaffold placed in a bioreactor. A seeding process using a liquid containing cells (chondrocytes) initiates the culture and an imposed continuous flow through the scaffold allows both the transport of nutrients necessary for cell-growth and of metabolic waste products. This work will attempt to contribute to the study of the hydrodynamics and transport through the fibrous scaffold at different stages of growth, both having a key role in the process of cell growth and on the final quality of the cultured cartilage.

The hydrodynamics in the scaffold and in particular the relationship between macroscopic experimentally accessible properties such as the permeability and the porosity have first been studied. For this purpose, the formalism of volume averaging is employed and the associated closure problem is solved numerically with an artificial compressibility algorithm on the basis of a finite volume scheme on a Marker and Cell type of grid. Fibrous media with different microscopic structures are studied.

Through a theoretical study, assuming local mass equilibrium, a macroscopic one-equation model describing the reactive transport (advection/diffusion/reaction) of the two species in a three-phase system composed of the cell-phase, a fluid phase and a solid phase is proposed. The volume averaging method is used to develop macroscopic transport equations and associated closure problems. Resolution of the latter over a unit cell representative of a pseudo-periodic medium allows the determination of effective macroscopic properties without any adjustable parameters. The dimensionless form of the closure problems involving advective, diffusive and reactive terms are numerically solved for any 3D geometrical configuration using a finite volume formulation using appropriate schemes. The velocity field input to the model is obtained by the resolution of the Navier-Stokes problem using a modified QUICK scheme and an Artificial Compressibility algorithm.

The numerical tool is then validated by comparing its results to those presented in the literature for 2-D unit cells and under-classes of our model (namely, diffusion, diffusion/reaction and diffusion/advection problems). The complete problem involving convection, diffusion and reaction in the three phase system is then studied for different parameters. More precisely, the influence of a cell Peclet number and the solid and cell volume fractions on the dispersion tensor has been studied.