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Homogenization of advection-diffusion and solid diffusion in poroelastic media for modelling transport of soluble factors in biological tissues

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This work has been motivated by the study of solid tumor growth, and more specifically, by the examination of the most frequently encountered type of pediatric primary bone tumors (osteosarcoma), characterised in their early stage by the formation of non-mineralised bone tissue, called osteoid [1]. As the tumor evolves in time, mineralisation of this growing tissue can take place.The objective of this work is thus to investigate the advection-diffusion of soluble factor such as calcium and phosphate [2] in the context of tumor mineralisation, to examine how the mineralisation of bone tissue may become a barrier to treatment in the context of drug transport [3], and also to determine how proteins and growth factors can play a role in tumor growth [4]. For this purpose, the mathematical modelling of advection-diffusion and solid diffusion in a poroelastic medium is firstly required. The present work is thus aimed at deriving the models by using asymptotic homogenization. Macroscopic models are derived by starting from the pore-scale equations. They describe a deforming linear elastic solid matrix saturared by a Newtonian incompressible fluid. They further include the convection-diffusion equations in the fluid phase, with a magnitude of the Peclet number that corresponds to a macroscopic advective-diffusive regime, and also account for diffusion in the solid phase. The local fluid/solid equations lead to Biot's model of poroelasticity on the macroscopic scale. Then, homogenization of the transport equations gives rise to three possible macroscopic advective diffusive transport models, that relate to three possible orders of magnitude of the diffusivity ratio: a model in which the solid diffusion only influences the accumulation term; ii) a model with memory effects; iii) the model of avection-diffusion in a deforming porous medium (with no influence of solid diffusion). Initially expressed by means of orders of magnitude of the diffusivity ratio, the domains of validity of each of these three models can be expressed in terms of relative orders of magnitude of two characteristic times. The three models contain a solute-solid interaction term, due to the advection regime, and are coupled to the poroelaticity model via the advection term.

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