Mathematical Methods and Models in Biosciences
June 15–20, 2025, Sofia, Bulgaria
https://biomath.math.bas.bg/biomath/index.php/bmcs

An upscaled model of multispecies biofilm in marine sediment

Luigi Frunzo, Ahmed Fathi, Maria Rosaria Mattei

Department of Mathematics and Applications,
University of Naples, Italy
luigi.frunzo@unina.it

A macroscopic model for biofilm growth in a homogeneous marine porous medium (i.e. marine sediment) is derived by upscaling the one-dimensional Wanner-Gujer multispecies biofilm model. The flow through the porous medium is assumed in a laminar and convection-dominated regime. The formal multiscale asymptotic method is applied to the mesoscale coupled system of elliptic-hyperbolic equations describing biofilm growth and evolution.

The proposed model hypothesizes a dual-species biofilm uptaking the same substrate. The loss of biomass due to the shear forces i.e. detachment process, and the attachment of bacteria clusters in quiet zones of the domain, i.e. attachment process, are modelled. Finally, the model considers the ecology of the suspended biomass and their interaction (through attachment and detachment) with the biofilm.

The upscaling method is flexible to consider any number of bacteria species and substrates, and can be extended to various biofilm processes and kinetics (e.g., multiple substrates consumption, metals sorption and precipitation). The upscaling procedures end up with a stiff system of hyperbolic equations that are solved numerically.

A numerical code has been implemented on the MATLAB to simulate model behaviors. The results prove model consistency and different simulation scenarios have been investigated by varying the following parameters: attachment velocity, detachment coefficient, and fluid flow rate. The mixed-culture biofilm assumption was found to significantly affect the overall system performance, and the model outputs qualitatively agree with the physical expectations.