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Role of local conditions of a turbulent boundary layer flow on the colonization and growth of a biofilm: direct numerical simulations and experiments

F. Coundoul (1,2), F. Moulin (1,2), T. Bonometti (1,2)

(1) INPT, UPS, IMFT (Institut de Mécanique des Fluides de Toulouse), Université de Toulouse, Allée Camille Soula, F-31400 Toulouse, France , (2) CNRS, IMFT, F-31400 Toulouse, France

The epilithic biofilm, aggregate set of phototrophic organisms growing on the bottom of rivers, plays an essential role in the functioning of river ecosystems: storage of nutrients, carbon and nitrogen cycle and nutrients resource for higher trophic.

To improve the modeling of hydro-ecosystems such as the Garonne river, it is necessary to introduce a functional compartment for the biofilm and to adequately describe its interaction with the flow (locals hydrodynamic conditions). This is also true for improving the management of artificial waterways such as irrigation channels where the growth of biofilm and his detachment can caused significant problems.

The interaction between the biofilm and water flow was not previously taken into account explicitly in the predictive models of the river continuum: Yet the growth, senescence and the uprooting of biofilm heavily depend on local hydrodynamic conditions and vice versa, structure, cohesion and control the thickness of the biofilm structure (velocity fields at the local level) of the water column. It was shown (see Graba et al. [2]) that taking into account the local characteristics of the hydrodynamic (the friction velocity u*, hydraulic roughness ks and the displacement height d) in classical models of evolution of the biomass leads to a better prediction than when depth averaged hydrodynamic quantities (debit Q, average volocity Um) are used.

Around this question of the interaction between the epilithic biofilm and flow, an experimental study in a laboratory channel at the Institut de Mécanique des Fluides de Toulouse was realized by Moulin et al. [1] using PIV measurements (Particle Image Velocimetry) to quantify hydrodynamics over hemispheres covered with biofilm. In the initial phase of colonization and biofilm growth, a very specific topology in the distribution of biofilm in the hemispheres was observed, which seems to depend on local flow conditions inaccessible to PIV measurements presented in Moulin and al. [1]. (which are limited to the inertial sub-layer and the upper roughness sub-layer).

The objective of this study was to investigate the role of local conditions of a turbulent boundary layer flow in the development of a river biofilm especially in the phases of colonization and initial growth by using a numerical approach.
A direct numerical simulations (DNS) of a turbulent boundary layer flow over a bed of hemispheres was performed using an Immersed Boundary Method. The validity of the scheme was checked by comparison with experimental and numerical results for a flow above a bed of regular cubes. Numerical simulations for a flow above hemispheres are presented and compared with measurements performed during river biofilm growth experiments in a hydraulic flume. The access to local flow conditions in the numerical simulation leads to a better understanding of the morphology of the colonization patches observed in the experiments.

References:
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[2] Graba M., Moulin F., Boulêtreau S., Garabétian F., Kettab A., Eiff O., Sanchez-Perez J.M. et Sauvage S.. Dynamics of epilithic biofilm biomass in artificial rough, open-channel flow: Experimental and modeling approaches. Water Resour. Res., doi:10.1029/2009WR008679, in press.