Kinetic and metabolic modelling of aquatic phototrophic biofilms

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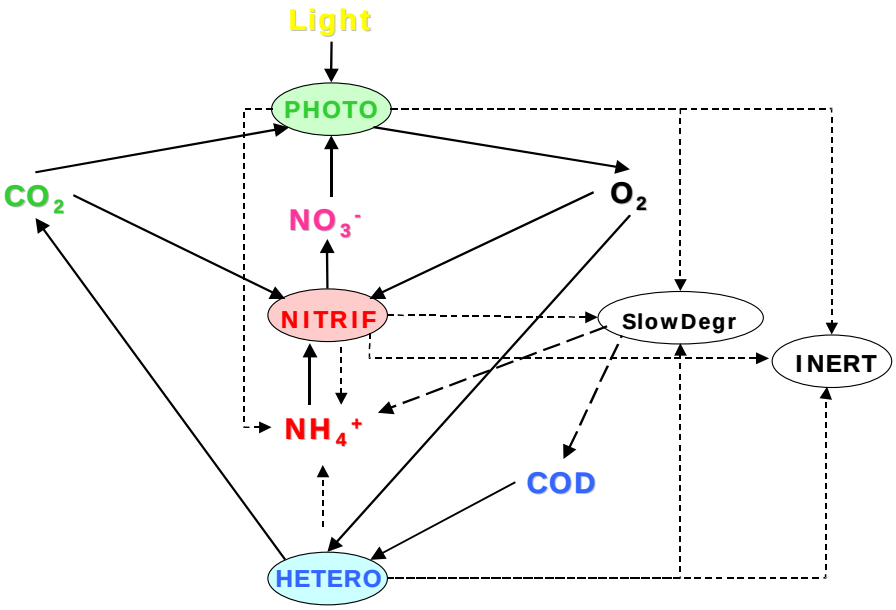
Description

Phototrophic biofilms are light-driven microbial communities attached to a solid substratum. They can be found virtually anywhere in nature, and they are commercially interesting for several reasons. On the one hand, they can cause biofouling, for example on ship hulls or on submersed (marine) installations. Hence, their control via the development of new antifouling-agents is of great importance.

Phototrophic biofilm in a lab scale setup

On the other hand, phototrophic biofilms are used in the bioremediation of polluted waters, e.g. nutrient-rich effluents with low organic loads. Their application in these systems is advantageous because phototrophs use light and carbon dioxide for growth rather than organic carbon. Most phototrophs produce oxygen during light periods and excrete organic substances (as exudates or extracellular polysaccharides), thus fuelling the growth of other microbial communities in the biofilm. During daytime, aerobic bacteria, e.g. nitrifying autotrophs converting ammonia to nitrate, may greatly benefit from the presence of phototrophic organisms in the biofilm due to the extra oxygen-supply, especially in the inner zones of thick biofilms that otherwise are often oxygen-depleted. At nighttime, when no oxygen is produced, anoxic or anaerobic environments may be prevailing inside thick biofilms. This creates favourable conditions for other physiological groups, such as anaerobic hetero-trophic denitrifiers, which are able to convert nitrate into nitrite and eventually into nitrogen gas, which is released into the atmosphere.



Competition between species in a phototrophic biofilm

Furthermore, the utilization of carbon dioxide by the phototrophs leads to a shift towards alkaline pH in the inner diffusion-limited layers of thick biofilms during daytime. This creates favourable conditions for phosphate precipitation, thus additionally contributing to nutrient removal from the wastewater.

Our project is situated within the frame of the EU-sponsored PHOBIA project, which unites several European experts in their efforts to develop a unifying concept for phototrophic biofilms and their applications. Our focus is on the mathematical modelling of complex interactions between different physiological groups present in phototrophic biofilms (see above Figure). The rate-based model encompasses metabolic mechanisms of different microbial groups, as well as chemical processes such as acid-base equilibria. It integrates experimental data obtained by several other PHOBIA partners, which are used as model parameters, as well as for model validation. The validated model will eventually be made public as a tool for in-depth analysis of phototrophic biofilms, and for simulating the performance of phototrophic effluent treatment installations.

References

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Web resources

PHOBIA
Biofilm modeling at Delft University of Technology