Oxygenic photogranules: from ecology to wastewater treatment

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Abstract

The syntrophic interaction of heterotrophic and phototrophic bacteria with an exchange of CO_2 and O_2 have been known for a long time. There have been ample suggestions in the literature of using this interplay for biotechnological application where organic matter is oxidized, e.g., in wastewater treatment. However, severe bottlenecks, for example the separation of bacteria and microalgae from the treated wastewater, have made the application challenging.

The recently discovered oxygenic photogranules, with filamentous cyanobacteria as phototrophic microorganisms, overcome this problem. These roughly spherical, dense microbial aggregates with a diameter of several millimeters are easily separated from the treated water by settling. In addition, compared to the conventionally used activated sludge system for wastewater treatment, oxygenic photogranules combine two major advantages: (1) oxygen for the oxidation of wastewater constituents is produced in-situ. Costly external aeration is not necessary, however, artificial light may be necessary setting off the gain. (2) CO_2 and nitrogen species remain fixed as they are to a great extend incorporated into the growing phototrophic biomass.

The formation of photogranules is not well understood from a microbial ecological point of view even though it is crucial for the ecological engineering of photogranules, i.e., the design, management and prediction of ecosystem behavior using ecological theory. In our laboratory, we combine fundamental knowledge derived from experiments on the ecology of photogranules (e.g., community requirements for photogranulation; the relationship between light availability and microbial activity) with mathematical models describing mass transfer of metabolites in the photogranule matrix and biophysical properties of community members (e.g., morphology and motility of cyanobacteria). At the same time, we operate laboratory scale reactor systems to validate the fundamental principles and to suggest reactor conditions that optimize the biotechnological potential of photogranules. This potential includes the treatment of wastewater, the ecological engineering of the photogranule community to degrade specific compounds and the production of compounds with added value and nutrient recycling.

Oxygenic photogranules have been shown to treat domestic wastewater meeting typical effluent regulations. It is now time to decipher their formation to unlock additional benefits of this novel kind of microbial consortium in biotechnological applications like wastewater treatment.